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The "Northumberland" Clause.

RARELY indeed is a compromise welcomed by both parties to a dispute. Therefore the Select Committee of the House of Lords, under the chairmanship of the Duke of Northumberland, is to be congratulated upon the formulation of what will henceforth be known as the "Northumberland Clause"—a provision which has been received with satisfaction, if not with jubilation, by those representing the rival interests of gas companies and municipal electricity departments. We need not here refer to the question of municipal trading which is necessarily involved in the sale of electric current by local authorities. Nor do we now propose to add to the remarks upon this topic which have already appeared in our columns. In recent controversy various gas companies have exhibited much anxiety that the ratepayers should be protected against losses arising from the conduct of municipal electric supply undertakings, but the ratepayers themselves have done little to justify this gratuitous advocacy. A provision which has been a bone of contention for the last two or three years is the well-known Bermondsey Clause. This was placed on the Statute Book in 1902 as the result of opposition by the South Metropolitan Gas Company to the Provisional Order by which the Bermondsey Borough Council sought to extend their area of supply. The Company contended that provision should be made in the order to insure that the price charged for electricity should be such as to make the undertaking self-supporting, and that the Council should not be permitted to charge the rates with any deficiency. As a result of these contentions, a Committee of the House of Lords decided upon the insertion of the following stipulations :—

> The undertakers shall, once in every year, after the first year's working of the undertaking, cause to be laid before them a statement and balance-sheet of the accounts of the undertaking, drawn up in accordance with the form of accounts prescribed by the Board of Trade for a local authority under the Electric Lighting Acts 1882 and 1888, and the undertakers shall thereupon fix annually the charges to be made for the supply of energy in the then ensuing year at such rates (not exceeding the maximum rates specified in the principal order) so that as far as is reasonably practicable the revenue for that year shall not be less than the expenditure for that year.

The foregoing, which constitutes the Bermondsey clause, being thought insufficient to secure the full effects desired, a further qualifying clause was suggested. This having been first inserted in the Provisional Order of the Marylebone Borough Council, is now generally described as the Marylebone clause. Its object is to prevent the local authority from raising the price of current supplied for public lighting higher than the price charged to private

consumers having similar hours of supply. Thus, authorities to whom the clause has been applied are unable to disguise a portion of the losses, or to augment the apparent profits of their electricity undertakings by making unduly high charges for street-lighting current. Taken together, the Bermondsey and Marylebone clauses impose effective restrictions upon local authorities and guard the public against improper manipulation of the accounts. There are, however, serious objections to the general application of the clauses, and especially to the Bermondsey clause, for, although most acceptable to the gas companies, it is, in some respects, inimical to the true interests of the ratepayers. Municipal trade in electricity may be wrong in principle, but it is sanctioned by Parliament, and will inevitably be continued. Therefore every encouragement should be given to those who desire that it should pay its way. Losses must certainly be expected during the early stages of any commercial enterprise, and any attempt to check such losses by raising the price of the commodity would be perfectly futile. This ridiculous policy is what the Bermondsey clause particularly involves. A far wiser course is to reduce prices, of course within reasonable limits, so as to popularise the product, and to look for profits as the result of an increased demand. The aspect of the question here raised was fully discussed before the Duke of Northumberland's Committee at the instance of the Watford Urban Council and some other authorities, who are asking for the confirmation of Electric Lighting Orders. From the accounts presented by the Clerk to the Council we find that after taking into account all expenses, interest on loans, and repayment of principal, the following are the net results, from the commencement of the undertaking in May, 1899, to March, 1904 :—

Year	Dec. 1899 7 mths.	Dec. 1900 12 mths.	Mar. 1902 15 mths.	Mar. 1903 12 mths.	Mar. 1904 12 mths.
Deficiency	£1,049	£1,365	£185	£1,316	£181

Owing to a necessary alteration in the time up to which accounts were made, it is a little difficult to trace the progress of the undertaking, but a simple calculation shows that the deficiency for the first year was at the rate of £1,800 per annum, that for the next period was £1,365, the combined deficiency for the two succeeding years was £1,501, and for the year 1903–4 the deficit was only £181. Here there is ample evidence of improvement, although its progressive character is not definitely indicated by the manner in which the accounts are stated. It is clearly shown, however, that continued increase has been made in the quantities of current supplied year by year, a result attributable to the reduction of price made after March, 1902. This in itself is a strong argument against the Bermondsey clause, the real object of which appears to be the stifling of municipal electricity undertakings, in the interest of gas companies. The same view impressed itself upon the Duke of Northumberland's Select Committee, by whom a new clause was finally adopted to the following effect: (1) That the accounts of the undertakers shall be published annually in the form prescribed by the Board of Trade. (2) That the local authority, at the end of five years after the undertakers supply energy in the case of a new, and of three years in the case of an existing undertaking, and thenceforward triennially, shall, so far as is reasonably possible, revise its rates so that no loss shall be incurred by the ratepayers on the undertaking. (3) That nothing shall prevent a local authority from entering into a contract to supply electrical energy on special terms, but the rates charged in future contracts shall be either subject to revision at the triennial revision, or rise and fall—but not, except by consent, below any minimum named in the contract—*pari passu* with the general electric lighting rates fixed at the triennial revision, and the promoters in such case will decide which of these alternatives they prefer to be inserted in the order.

Attention should be directed to the fact that the object of the new clause is not to discourage or prevent more frequent revision of rates for current, should this be thought desirable by local authorities; and the satisfactory announcement is made that the clause, which has now been drafted in proper legal form and approved,

will be inserted in all the electric-lighting orders recently brought before the Committee, in substitution for the objectionable Bermondsey clause. It is to be hoped that the provision in question will be generally adopted in connection with future legislation of similar character, so that the local authorities may have every opportunity of conducting their electricity departments on such lines as may lead to lower rates concurrently with profitable results. If, with such advantageous conditions, these bodies prove themselves incapable of securing success, the sooner they are debarred from entering upon enterprises of the kind the better it will be for the community at large.

The Structure of the Atom.

FROM the earliest days of scientific investigation the problem of the ultimate structure of matter has had a peculiar fascination for the minds of men. To take a solid mass and break it up into fine fragments is a simple matter; but when further division is no longer possible by any means at our disposal, the mind will not allow us to rest content there and say "Here is finality," but forces us to look beyond the bounds of practical experiment and carry on the analysis by the light of reason. Part of the attraction of this problem no doubt lies in the highly speculative character of any attempt at its solution; the most one can do is to build up a theory, reasonable in itself, which fits in with such experimental facts as we know; but there must always be kept in view the possibility, perhaps even the expectation, of some new fact being discovered which cannot be explained by that theory, and which is in itself sufficient to upset it. It is otherwise in the case of the great fundamental laws of the universe, such as the law of gravitation or the law of the conservation of energy. Not only has no fact been discovered that is antagonistic to either of these laws, but we have the firm belief that no such fact ever will be discovered, and we therefore make free use of these laws in seeking to determine what consequences will result from particular facts given. But in approaching the problem of the finite or infinite divisibility of matter no such certainty can be ours; we may accept the laws which have been deduced from the atomic theory, and measure the masses and other physical and chemical properties of the atoms to which matter is by it finally reduced, but there is always the mental reservation that in these atoms of Dalton we have not arrived at finality, but must still continue the search into the unknown.

In very recent years a great amount of investigation has been made in the realm of molecular physics, and results have been obtained which, though not yet conclusive, have undoubtedly led us further on the way to a solution of our difficulties, and have opened up new lines of thought and of investigation. Before we consider some of these investigations more particularly, let us look more closely at the exact position we occupy if we accept Dalton's atomic theory as our starting-point. We have there the assumption that each chemical element consists of extremely minute indivisible particles or atoms, and that the atoms of any particular element are exactly alike but are different in weight and in other respects from those of another element. If these atoms, then, were the final subdivisions of matter, we should have the universe reduced to a comparatively small number of discrete units, having no very definite relationship to one another, and showing nothing of that unity which is prominent throughout nature. But this hypothesis does not appeal to reason, and, as the late Mr. Samuel Laing has put it—

"No one can suppose that this is really the ultimate fact, and that original matter really consists of seventy indivisible units, ranging in weight from the 1 of hydrogen to the 240 of uranium, and more than half of them consisting of exceedingly rare elements which play no appreciable part in the construction of any form of matter. The mind refuses to accept the conclusion that such little mole-hills as yttrium, zirconium, and gallium, only known as minute products of a

few of the rarest minerals, really present insurmountable obstacles to the science which has scaled alps, measured light-waves, and weighed stars."—"Problems of the Future," chap. ii.

Thus we are led at once to attempt to reduce these atoms to a still simpler form, and to connect them in some definite manner with each other, as, for example, by showing that they are in reality but different modifications of one "primordial atom." Here the chemist cannot help us, but the physicist has pursued the investigation, and the results obtained in recent years from the examination of the electric discharge in vacuum tubes, of Röntgen rays, cathode rays, and radium rays have thrown new light upon the subject In this line of research there has been no more active worker than Professor J. J. Thomson, of Cambridge, whose brilliant speculations on the subject under discussion we are now about to notice.

From his investigations on the conduction of electricity in gases, Professor Thomson was able to measure not only the charge on the "carriers" but also their mass, and he has found that the mass of the carrier of the negative charge is one-thousandth of that of the atom of hydrogen. Thus we have at once arrived at a mass exceedingly more minute than that which is by the atomic theory regarded as the smallest possible. But the investigation does not stop here. To each of these small negative ions Professor Thomson gives the name "corpuscle," and negative electrification, when the pressure is low, so that only a very small quantity of ordinary matter is present, is regarded as an assemblage of corpuscles. The positive ions, on the other hand, are always found associated with masses which are comparable with the masses of the ordinary atoms of the gases in which they occur. On this corpuscular theory, therefore, a positively electrified body is one which has been deprived of some corpuscles—

"positive electrification is always associated with ordinary matter, while negative electrification may or may not be, according as the corpuscles are or are not attached to molecules of ordinary matter."

A negative corpuscle, then, which is entirely free from ordinary matter, has still a *mass* which Professor Thomson shows to be electrical in origin, and the question is therefore at once raised whether the masses of all bodies may not have the same origin.

If this be so, what is the structure of the atom? In his recent work, "Conduction of Electricity through Gases," Prof. Thomson throws out a general suggestion which he has since elaborated more fully. At p. 535, he says :—

"It is easy to imagine a form of atom for which the whole mass would be electrical. For suppose that the atoms are made up of a large number of negatively electrified corpuscles, each corpuscle being associated with its corresponding positive charge, and suppose that these positive charges are spread over a much greater volume than the corpuscles, the aggregation thus formed would consist of a distribution of positive electricity through a sphere, the corpuscles being distributed through the sphere in such a way as to be in equilibrium under their own repulsions and the attractive force to the centre of the sphere arising from the positive electrification."

In the *Philosophical Magazine* for March of this year, Professor Thomson has enlarged on this suggestion, and has worked out several intricate mathematical problems raised by it. In the most general case, in which the corpuscles within the sphere would be free to move in all directions, the atom would be made up of a sphere of uniform positive electrification enclosing a number of concentric spherical shells containing negative corpuscles, the number of corpuscles on each consecutive shell decreasing as we go from the outer sphere to its centre. The analytical difficulties, however, in the way of determining the distribution of corpuscles when thus arranged in shells, have prevented the author from arriving at a general solution, so for the present he has confined himself to the case in which the corpuscles within the sphere are arranged in plane-rings. He shows that, for any number of corpuscles exceeding five, stability for that ring cannot be obtained unless other corpuscles be placed within it, the number required for this purpose increasing with the number of corpuscles in the ring. Further, these corpuscles required to produce stability will arrange themselves in a regular fashion round the centre. Thus a ring of 12 corpuscles requires

7 corpuscles inside it to produce stability, and these 7 will arrange themselves in an inner ring of 6 with one at the centre. Where the corpuscles can move at right angles to the plane of their ring as well as in their orbit, the different rings will adjust themselves in parallel planes, so that the repulsion between them is balanced by the attraction exerted upon them by the positive electrification of the surrounding sphere. The general problem is to find the distribution of N corpuscles, each carrying a negative charge e, when so arranged within the positive sphere that the number of rings is a minimum—that is, each ring contains as nearly as possible as many corpuscles as the corpuscles within the ring can hold in equilibrium. The solution of this problem leads to very interesting results, as Professor Thomson is able to show that systems built up of corpuscles in this way will possess properties analogous to some of those possessed by the atoms. In the first place, he shows that the various arrangements of corpuscles can be classified in families in which each member is formed from the preceding member by the addition of a single ring of corpuscles, the arrangement in all the other rings remaining the same; and such a family would correspond to elements in the same group in the arrangement of the elements according to the periodic law—that is,

"they form a series which, if arranged according to Mendeléef's table, would all be in the same vertical column." Further, "the gradual change in the properties of the elements which takes place as we travel along one of the horizontal rows in Mendeléef's arrangement of the elements is also illustrated by the properties possessed by these groups of corpuscles."

For the full and most interesting discussion of this matter we must refer readers to the original Paper; here we can only note briefly the general result. We need only remark in conclusion that on this hypothesis as to the structure of the atom, it is possible to account for radio-activity, as it is found that certain systems of corpuscles are stable when the velocity of rotation of the corpuscles is above a definite critical value, but become unstable when the velocity falls below that value, and it is shown that a system of this nature would give to the atom possessing it radio-active properties.

These ingenious speculations, which Prof. Thomson has made as a result of his valuable investigations, not only show the brilliant mind of this physicist but are in themselves of great importance. They are not conclusive, but they certainly open up new avenues rich in promise for the explorer. Especially are they valuable in that they provide at last a means of reducing all the diverse chemical atoms ultimately to one and the same unit, and are thus on the lines in which reason, without experiment, has led us. The remarkable suggestion that in the end all mass may be shown to be due to electricity and nothing else, may not be easy to grasp at present, but if it should be true, may we not lay down a new and fundamental proposition that "Nothing exists but Energy"?

High-Speed Locomotives.

NOTHING has been more noteworthy of late years in connection with railway practice than the rapidly increased power of the locomotive. The heating surfaces of boilers have been extended, grate areas have been proportionately enlarged, and pressures have been raised by as much as 50 per cent. One point worthy of comment in connection with this development is that practically no increase of cylinder dimensions has been made, notwithstanding the great augmentation of the loads to be drawn. Locomotive engineers are by no means agreed that increased cylinder dimensions are desirable, and there are practical objections to the construction of locomotives with cylinders of exceptional diameter. Hence endeavours in the direction of greater capacity have been confined to the multiplication of the cylinders themselves. Four-cylinder simple locomotives have been tried with indifferent success, and lately the suggestion has been made

that three-cylinder simple engines might be adopted with advantage. It is by no means an unreasonable contention that the mechanical part of a locomotive should be made so as to overtake what may be termed the physical department of the same machine. In other words, it would be advantageous to proportion the cylinder capacity so that the steam, at whatever pressure it be supplied, could be more fully and more economically utilised than at present in the form of mechanical power.

The compound principle is looked to by many as being the means of securing a higher efficiency, and, in fact, some figures recently made available show that very considerable economies have been effected in this line, in the direction of coal consumption, by the adoption of this system. Interest in the question has further increased in consequence of the experiments made on the Great Western Railway by Mr. Churchward, and of the Paper on "Compound Locomotives" recently read by M. Sauvage, before the Institution of Mechanical Engineers. We need not here enter upon a detailed comparison between compound and single locomotives. Mr. Churchward has demonstrated in a conclusive manner that the latter type is capable of giving practically the same power as the former, although he is not yet in a position to form any definite opinion as to the relative values of the two types, and prefers to say nothing at present on the question of coal consumption.

It is abundantly evident, however, from the splendid performances of which the results have lately been made public, that high rates of speed are attainable, whatever be the form of engine adopted, providing due regard is paid to the essentials of scientific design and construction.

This brings us to the important question of resistance, which has assumed prominence as a direct result of the high speeds attained by modern locomotive engines. Attention was drawn to this subject by the German experiments on high-speed traction, originally commenced in the year 1891, the chief point for consideration being, how far the resistance to be overcome will permit further advance in the speed of trains hauled by steam locomotives. The formulæ hitherto at the disposal of the railway engineer are based upon speeds not exceeding 60 miles an hour, a limit long since passed by express trains and notably by the remarkable records to which we have already referred. Resistance to the progressive movement of a train may be determined, when uniform speed has been attained, by calculating the total force exerted by the aid of indicator diagrams; then deducting the drawbar pull, as denoted by a dynamometer, we have for difference the total resistance of the locomotive alone. This method presents two drawbacks: (1) That it is difficult to maintain a uniform speed of running, and (2) that indicator diagrams do not afford accurate data at high speeds. A second method of determination is to shut off steam at any given point and to calculate the operative force from the speed variation In applying this method the engine is usually allowed to come to a standstill on a downhill gradient, and the resistance to motion is equal to the retarding force plus the acceleration due to the gradient. This method is also open to objection. For instance, after steam has been shut off the cylinders act as piston pumps and thus introduce a considerable element of error, as the resistances thereby set up vary with the dimensions of the pistons, the design of the valves, and the speed of the engine. In order to eliminate this source of error a series of experiments was commenced in 1901 by MM. Von Borries and Frank with compound high-speed locomotives of the Prussian State Railway, with the result that formulæ were obtained expressing the average results, but which, still requiring modifications and corrections, do not constitute a definite solution of the difficult problem investigated.

With regard to the applicability of steam locomotives to high-speed traffic, M. Von Borries, in a contribution to the Society of German Engineers, shows that within certain limits the efficiency of an engine increases with its speed chiefly because combustion is more perfect and the steam is better utilised; but that, on the other

hand, when 300 revolutions per minute is exceeded friction in the steamports, and other details, causes a reduction of efficiency. According to a formula deduced by M. Frank, each square metre of boiler heating surface should develop at the periphery of the driving wheel $0{\cdot}617\sqrt{v}$ h.p., and from this he concluded that the power available should be from 6·2 h.p. per square metre of heating surface, with $v = 100$ kilometres to 8·7 h.p. with $v = 200$ kilometres. These results, however, are too high, for actual trials—one with an engine of the Baden railways, and another with the most recent engines of the Henschel type – show that the boiler performances were respectively with $v = 110$ kilometres, 6·7 h.p., and with $v = 123$ kilometres, 6·6 h.p. in each case per square metre of heating surface. These figures are sufficient to suggest that so far as increase of speed is concerned we have already reached the limits of steam economy.

In the two engines mentioned, and indeed in those of other German designers, the fronts are of wedge-shaped form, the object being to furnish a simple and inexpensive means of improving the performance by reducing air resistance. The principle underlying this detail—applied for thousands of years in the design of boats and ships, and more recently in the design of motor vehicles—has been strangely neglected by locomotive engineers, a circumstance only to be accounted for on the hypothesis that the only criterion of efficiency is power without regard to fuel economy.

Turning now to some facts elicited during recent discussion of the Paper by M. Sauvage, we find that the first evening of the discussion attention was directed to the admirable performances of the De Glehn four-cylinder compound locomotive in France, and statements were made leading to the conclusion that the resistance offered by this type of engine must be considerably less than in British locomotives. The question of resistance to locomotives running at high speeds is of complex character, for in addition to commonly recognised forces causing resistance to locomotion there are others of more obscure character, which being apparently evidenced within the machine give rise to what may be distinguished as "internal resistance."

It is known that the size of the wheels and the arrangement of mechanical features have a very important effect on the running of an engine. This point was well illustrated in the remarks made by Mr. Ivatt, who, in the course of the discussion to which we refer, produced diagrams taken from Great Northern engines showing the relation between horse-power and drawbar pull. Indicator diagrams show the power developed in the cylinders, but not the proportion of the total power exerted in the form of drawbar pull, because—and particularly at high speeds—much of the cylinder power is absorbed in overcoming the internal resistance of the engine itself. With increase of speed, internal resistance increases and drawbar pull diminishes, until a point is reached at which the engine is only able to move itself and exerts no pull at the drawbar. This is a remarkable development which will be more fully realised by examination of the following figures, taken in a purely approximate manner from two curves given by Mr. Ivatt :—

COMPARISON OF DRAWBAR PULL FOR TWO LOCOMOTIVES AT DIFFERENT SPEEDS.

Speed in Miles per Hour.	Drawbar Pull in Tons.	
	Eight-coupled Goods Engine.	Single-wheeled Express Engine.
10	7·6	(3·8)*
20	4·6	3·0
30	2·0	2·5
40	0·9	2·1
50	(0·1)*	1·8
60	—	1·3
70	—	0·8
80	—	0·4

*Computed.

The eight-coupled engine had small wheels and was designed for an average speed of about 20 miles an hour, and although exerting a far greater pull at the start exhibited a very rapid falling off as

speed increased, particularly in comparison with the express engine. The diagram from which these figures are roughly measured was prepared from records obtained under ordinary working conditions, and does not represent the highest capacity of the two engines, but rather the relative drawbar pull at the speeds denoted. While simply illustrating the behaviour of two extreme types of engine, the diagram helps to show the advantage to be derived from what is termed a "free-running" engine. The amount of power absorbed by a locomotive is something astonishing to the uninitiated. As Mr. Sisterson told his hearers at the Institution of Mechanical Engineers, the power absorbed in running an engine weighing from 80 to 90 tons, together with its tender, amounted to between 800 and 900 i.h.p., when the speed of about 70 miles on the level was attained. This represents a resistance of very nearly 60 lbs. per ton of engine and tender. Taking another example, based on a trial trip of the "Precursor," a new type of engine designed by Mr. Whale for the London and North-Western Railway, we find that during a run between Crewe and Rugby at 61 miles an hour, the drawbar pull was 2 tons, equivalent to about 730 i.h.p., while the engine was developing 1,174 i.h.p. Here we have $1,174 - 730 = 444$ i.h.p., representing resistance of the engine and tender alone. It would be very interesting to know exactly what becomes of such very considerable amounts of power, but no one is prepared with a precise explanation. Air resistance we know accounts for a large proportion, friction also absorbs some, but not very much, and practically the remainder is dissipated somewhere in the engine. To ascertain precisely how this balance of power is eaten up should now be the aim of every locomotive engineer; but the inquiry will necessarily be arduous, and demands the co-operation of all concerned in the design and construction of locomotives. One or two useful suggestions on this score have already been made by Mr. Ivatt, who points out that by dividing the work between four cylinders the reciprocating weights balance each other, preventing vertical disturbance and thereby tending to diminish internal resistance. Again, he points out that by keeping down the throw of the coupling rods an important reduction of internal resistance should be effected.

Although it would be premature to express any definite opinion upon this question, which has quite recently been forced upon the attention of railway engineers, and cannot yet be answered by the most eminent experts, it seems certain that the various details which go to make up a modern locomotive might be so modified, and their arrangement so contrived, as to effect a very great improvement. But the manner in which such modifications are to be executed constitutes the problem—or at least one problem—which locomotive experts alone can attempt to solve with any hope of success.

Accuracy in Testing Materials.

By W. C. POPPLEWELL, M.Sc., A.M.Inst.C.E.

ALTHOUGH tests in tension, compression, and bending are frequently made on material of all kinds, it is only in the case of structural iron and steel that large numbers of systematic tests are carried out to satisfy the standards laid down in the specifications of the engineer. By far the most largely used of the structural metals is mild steel, and the methods employed in the testing of this material and the results expected, have become more and more standardised; and, although we in this country are considerably behind our *confrères* in other parts of the world in the standardisation of test results, we are approaching much nearer to perfection in this respect, and may reasonably hope that in the not-very-far-distant future the efforts of the Engineering Standards Committee may have made it possible to establish standards of quality which shall be generally adopted by all engineers engaged in constructive work. How far this standardisation will be carried, and how long it will take to carry it into effect, is impossible to foretell; but, quite independently of the sizes which may be adopted for test-bars, it is necessary that the methods of carrying out the tests shall be uniform, and especially that the degrees of accuracy aimed at in the different operations be properly understood. In the case of tension tests of mild steel the two results which are chiefly relied upon to indicate the quality of the material are the "maximum stress" and the "elongation after fracture." To these may be added the "yield point stress" and the "reduction of area," though less importance is attached to these than to the two first mentioned.

The stresses, both "maximum" and "yield point," are usually expressed in Great Britain as so many tons on each square inch of the original area of the cross section. To find any stress, two quantities require to be determined, namely, a load or force and one or two linear measurements, none of which can be obtained with absolute accuracy.

It will be the object in what follows to discuss the degrees of accuracy aimed at in the various operations, and how far it is possible to attain to these ideals. In doing this it will be necessary to confine ourselves, in the first place, to standard tension tests of iron and steel; and while doing this to only deal with the quantities which are generally depended upon to give the necessary information to engineers as to the quality of the material they are using—namely the stresses at the yield point and the maximum load, as well as the elongation of a certain length of the specimen and the contraction of the section after the bar has been broken. But even with the present limitations the discussion may not be unprofitable in so far as it will serve to indicate in a general way what are the influences which tell for and against accuracy, and how far these are important as bearing upon actual constructive work.

The Degree of Accuracy Necessary.

In order to see how far accuracy in testing is likely to influence the stability, durability, and safety of a given piece of work, it will be useful to consider a typical example. Let us take the case of one of the tension-bars of a lattice girder-bridge. What determines the size of this bar? First come the general dimensions of the bridge; these are fixed by circumstances which do not allow much latitude for variation, so that these dimensions may be regarded as absolutely fixed. Next come the loads upon the structure, fixed and assumed, from which the stresses in the various parts are calculated, with what may practically be said no error. How far the actual loads which come upon structures approach the calculated stresses is difficult to say.

The next stage consists in proportion-

ing the parts so as to resist the forces which have been calculated as likely to come upon them. It must often happen that the assumed maximum loads never do come upon the structure, and in this way there is often a considerable margin of safety provided during the process of estimating the loads. When proportioning the parts of a structure, the usual plan is to allow such dimensions that the estimated loads may cause a certain "safe stress" to come upon the material, this safe stress being always found by dividing the maximum stress as given by test results by an arbitrary constant called a "factor of safety." What does all this mean? In the first place, a margin is left in determining the loads upon the structure sufficient to cover all possible emergencies, that is to say, the maximum loads are such as are not at all likely to come upon the structure, even under the worst conditions; and, in the second, a further large margin is left to provide for any possible defects in the material. It has often been pointed out that all this free use of margins of safety denotes a degree of ignorance which ought not to exist, but at the present time there is a good deal to be said in its favour. In the existing state of our knowledge of the stresses produced in structures and parts of machines by known forces, it is impossible to do more than form what are really but rough approximations, except in the case of the simplest parts. Very often the assumptions made use of in the calculations are only approximately true, and any departure from the conditions assumed may cause considerable changes in the stresses. For instance, the stresses in framed girders are based on the assumption that the bars are all connected by pin-joints, whereas in many cases stiff-riveted joints are made use of, and it is impossible to say how nearly the actual stresses approach those which have been calculated. At the same time, it must be admitted that abnormal stresses produced in this way may often be relieved by a slight yielding of the material beyond the elastic limit, and in this way the whole structure thrown into a state of ease.

The factor of safety chosen, when divided into the maximum stress, is supposed to give a safe stress which is well below the elastic limit of the material and, at the same time, provide a small allowance to cover emergencies. Take, for instance, the case of a mild structural steel having a tensile strength of 30 tons per sq. in. If a factor of safety is used of, say, 5, the safe stress is 6 tons per sq. in., and the parts are so proportioned that at no part shall a greater stress than 6 tons per sq. in. come upon the material. The elastic limit—or, rather, the proportional limit—of this material will probably be 7 to 9 tons per sq. in., so that the actual stress is well below the stress which will produce any permanent effect on the material; but, after all, not so much below as one might think. It must be remembered that even if the proportional limit should be exceeded to a small degree, this limit will be raised by the loading without necessarily reaching the yield point, and without causing any but a very small permanent stretch in the steel.

Even at the present time it is very probable that working stresses might be slightly raised in many cases without risk of failure. In this way the cost might often be reduced and material saved. Our knowledge in this direction is still very limited, especially that relating to the elastic properties and the effect of repeated and reversed loadings. When more is known about these matters it is very likely that much greater stresses will be put upon materials without any fear of injury and with much greater certainty as to the result.

From what has just been said about the use of safe stresses in designing structural parts, it would seem that in the determination of the maximum stresses from which the safe stresses are estimated a very high percentage of accuracy is not necessary, in view of the relatively large margins allowed in the several steps followed in working out the sizes of the parts.

It has been found convenient to rely upon the maximum stress sustained by the test specimen as the ultimate criterion of strength, and from this the safe stresses are deduced as we have just seen, and consequently the determination of this maximum stress—or, as it is also called,

"ultimate stress"—is always regarded as the most important part of an ordinary commercial testing operation. The reasons for this are several. Although in the great majority of tests the yield-point stress is also found, the precise position of this point in the range of stress to which a test-bar is subjected is not so very easily found, and is never so definite as the maximum stress. Under the ordinary conditions of testing, the maximum load occurs at a very definite point, about which there can be no possible mistake. On the other hand there is a good deal of difference in the ways in which different experimenters find their yield load, and the difference in the method may, to a very considerable degree, alter its position. Also, in the case of some of the higher-carbon steels, steels containing other alloys besides carbon, and steels which have been hardened, there is no point which can be properly called a yield-point, and it is really the proportional limit which has to be found in such cases. The finding of the proportional limit involves both time and care to an extent not always possible in commercial testing, so that the maximum stress alone must be relied upon to provide a criterion of strength.

Besides the yield stress and maximum stress, it is also usual to find the ultimate elongation on one or more given lengths. Specifications generally state that certain results must be attained in these directions, but the finding of the maximum stress is the most important of all the test results, and with this in view it will next be desirable to investigate the various influences which tend for and against the attainment of high degrees of accuracy.

It may be added in this connection that, although the ratios which the proportional limit and the yield-point bear to the maximum stress are not by any means constant, even in metals which are in most other respects similar, it is rarely that the yield-point load falls lower than 50 per cent. of the maximum. For this reason the latter may be taken as a convenient measure of the elastic strength.

In view of the points which have been mentioned, it is now usually held to be sufficient if the load on a test specimen, as given by the machine, is within 1 per cent. of the true value. This has been frequently stated by the most eminent authorities upon the subject of testing.

Accuracy in Determining Stresses.

The finding of the stress upon a test specimen, whether it be the maximum or some other stress, involves two separate determinations—namely the load upon the bar and the area of its cross-section. Of these the former depends upon the readings of the testing-machine scale, and the latter upon one or more measurements taken with a pair of calipers. In any given case a certain degree of accuracy is attainable in each of these two operations, and these two combine to limit the accuracy of the stress determination. Let us take the accuracy of the machine first.

Accuracy of Testing Machines.

When a bar is loaded in a testing machine the magnitude of this load has a definite value, and the indications of the machine give it as some other value, differing from the true one by only a small amount. The important question is, how near is the given value to the true load, or what is the percentage of error to be looked for in any given case? It may be said at the outset that most testing machines of the best known types, when in good condition and in the hands of experienced observers, may be expected to give indications of load to well within 1 per cent. of the true values.

There are three influences which may affect the accuracy. In this country, at least, nearly all the testing-machines used by steel-makers and in testing laboratories depend ultimately on either a dead weight or weights, whose load acts through some multiplying gear; or upon the pressure exerted by a column of mercury. The first factor affecting the general result is the accuracy of these weights; about this there should be no doubt, because it is always possible to procure weights whose values differ from the standards to only a very minute extent, and the same thing

is true of the accuracy possible in a column of mercury.

The second factor is the precision and accuracy of the graduation of the reading scale, and in this is involved also the accuracy of the ratio of the multiplying leverage through which the weight acts. That is to say, assuming the weights to have their true value, and the total leverage to be precisely what it professes to be, there still remains a possibility of inaccuracy in faulty graduation of the reading scale. Either the actual distances marked on the scale may be too small or too great, or the marking may not be uniform. These are fundamental errors, and their total effect ought to be reduced to a very small quantity once for all during the construction or first calibration of the machine. There should be very little variation of the error, except in the case of the leverage, which may become altered in lever-machines, owing to the distortion of the knife-edges caused by constant use; and means should always be provided whereby these can be checked from time to time.

The most frequent cause of error in the readings given by testing-machines of all kinds is the friction of the moving parts giving rise to want of "sensitiveness." This lack of sensitiveness is due, in the case of lever-machines, to the friction of the knife-edges and of the frame which transmits the load from the specimen to the weighing-apparatus; in fluid pressure-machines there is a small amount of piston-friction, although this is always reduced as far as possible; diaphragm-machines give the least trouble in this direction, and are by far the most sensitive.

The smaller the fraction of the load which produces an indication on the scale, the greater is the sensitiveness of a machine said to be. The "sensitiveness" is usually expressed as the percentage of a given load, which will produce some stated movement of the indicator. In the example which will be given later, the full significance of the effect of sensitiveness will be more apparent.

Calibrating Testing Machines.

It is the exception rather than the rule for a testing machine to be so fitted up that it can at any time be completely tested for sensitiveness and accuracy, and very much is left to the makers. Fortunately the makers of testing machines are, as a rule, very reliable in their work, and take every care to reduce errors and causes of error to a minimum. But however nearly perfect a machine may be when it leaves the maker's hands, it very frequently happens that, owing to various causes, such as want of care in using, shocks, and even ordinary wear, may change the condition of a machine for the worse.

It would therefore seem necessary to recalibrate machines at frequent intervals of time, but there are difficulties in the way. To be able to calibrate a testing machine it is desirable to have a number of dead-weights of large capacity, and, of course, lifting tackle is needed to move these weights. In addition to the weights, which must be themselves accurate, and consequently costly, additional levers, links, shackles, and so forth are required. So that for a machine to be easily tested at any time in reality means a considerable expense to the owner of the machine. But in spite of these objections the writer thinks that where a machine is to be used for anything better than ordinary rough work, the owner should be in a position to check his machine, and so be quite sure that its readings are reasonably correct. As an example of such an arrangement the following calibration test may be of interest.

Example of Calibration Test.

The test to be described is one carried out by the writer, and consists of the preliminary calibration of a 50-ton horizontal testing-machine by Buckton, the test loads being applied to the weighing-apparatus of the machine through a one-to-one knee lever supplied by the makers. The test was a preliminary one made before finally adjusting the machine after erection, and is quoted here mainly with the intention of illustrating the method of calibration.*

* A more complete description of the above calibrating apparatus will be found in Professor Nicolson's paper in the Proceedings of the Manchester Association of Engineers, 1903, p. 214.

The observations for sensitiveness and accuracy were made as follows :—

At the outset the arms of the one-to-one lever were very carefully measured by the writer in several independent ways, and were found to be so nearly equal that any variation from this equality was smaller than could be appreciated with the measuring appliances used. The lever was therefore taken as being what it professes to be, namely, a lever of two equal arms. It is quite possible that the knife-edges may become slightly deformed after being used a number of times, and it will be desirable to repeat the measurement from time to time.

After the lever had been put in its place, along with its cross-girder and suspension-links, and the machine carefully examined to make sure that everything was free and in place, the test loads were then successively applied; first two tons, and then, by successive increments of two tons up to 10 tons. When any given load had been applied, the poise-weight of the machine was adjusted until the weighing-lever was in perfect balance, as indicated by the central position of the pointer attached to the lever. It was found that for each test load there was a small range in the position of the poise-weight at any point within which equilibrium could be maintained. These limits were found in each case by first moving the poise-weight away from the zero of the scale until the balance was reached, as shown by the indicator coming to rest in its central position. This gave one of the limits. Then, after moving the weight about one inch still further from the zero of the scale, it was gradually moved back again towards zero until equilibrium was once more attained. It was found that the distance between the two extreme points was approximately three divisions on the scale. The divisions on the scale correspond to $\frac{1}{20}$ ton, so that these three divisions represent about 0·15 of a ton.

The reason for this difference arises from the friction of those parts of the machine which move when the weighing-lever moves. It must be remembered that when making each experiment the test load was hanging from the lever-arm, and so the load was continuously on the machine. When the poise-weight is being moved from the zero of the scale the movement causes the lever to fall and so raise the test-weight; and in doing this the poise-weight, at its present leverage, not only balances the force due to the test load itself, but also overcomes the friction of the machine. When, however, the zero of the scale is being approached by the poise-weight, the test-weight is descending, and so raising the lever to its horizontal position. In doing this the test-weight has to balance the force due to the poise-weight as well as overcome the friction of the machine. In the one case the friction acts against the poise-weight, while in the other it opposes the movement of the test-load and helps the poise-weight. The result is that the reading of the scale is greater in the former case than in the latter. It can be shown that the true reading when friction is eliminated is the mean of the two extreme positions as found. Thus, if we call I_{I} the scale-reading when balance is attained by the poise moving away from zero, and I_{II} the reading when the poise is approaching the zero; F the frictional resistance of those parts of the machine which move when the beam moves; and W the test-load; then, in the former case, $I_{\text{I}} = W + F$, and in the second case $W = I_{\text{II}} + F$; consequently $F = I_{\text{I}} - W = W - I_{\text{II}}$, from which we get the result that $W = \frac{I_{\text{I}} + I_{\text{II}}}{2}$. That is to say, the reading which truly corresponds to the test-load, when friction has been eliminated, is given by the mean of the two readings as found in the manner described.

To proceed with the test itself. Altogether 50 readings were taken for each test-load, 25 of these being when the poise was moving from zero and 25 with the weight approaching zero. As there were five different test-loads there were evidently five readings for each load in each position. In the table of results on the next page it is the mean values of each set of five similar readings that are given.

The last may be regarded as the true values, being reckoned as the means of the two extreme values, as we have just seen.

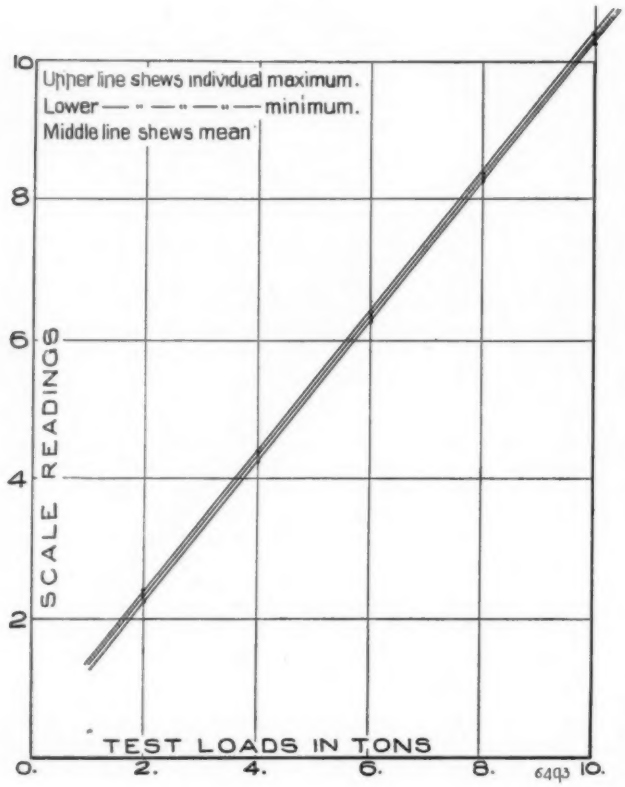


FIG. 1.

Scale Readings (Tons)	Proof Loads in Tons.				
	2	4	6	8	10
Upper Limit .	2·297	4·312	6·317	8·330	10·327
Lower ,, .	2·182	4·179	6·197	8·182	10·167
Average ...	2·239	4·245	6·248	8·261	10·297

The figures in the bottom line being taken as the true results, from these the errors are reckoned plus or minus, according as the readings in individual cases are above or below these figures. It will be noticed that these, what may be called corrected, readings are in all cases greater than the corresponding testing loads. This is obviously due to the fact that the zero of the scale had been placed too far back. On the machine in question the vernier scale, by means of which the readings are taken, can be set in any given position, so that the above discrepancy is easily corrected.

Below are given the mean percentage errors, plus or minus. These represent the differences between the first two lines of the last table and the figures on the third line :—

MEAN PERCENTAGE ERRORS.

(plus or minus) 2·58 1·56 1·10 0·96 0·76

The two following lines give the percentage errors again, but, in this case, taking the individual greatest or least for each test load :—

MAXIMUM ERRORS.

(all plus) 4·27 2·00 1·39 1·37 1·05

MINIMUM ERRORS.

(all plus) 1·80 0·93 0·50 0·65 0·58

In the accompanying diagrams, Figs. 1 and 2, are shown graphically the results which have just been given in tabular form. It will be seen here that all the errors—mean, maximum, and minimum —diminish rapidly as the loads increase. The curve of errors seems to be something in the nature of an hyperbola, with the zero line as asymptote, the curve becoming nearly parallel to the zero line at about 10 tons load. The "maximum errors" curve almost falls below the 1 percent. line, and the mean and minimum

curves fall well below this. This is what happens in the case of most testing machines, the percentage errors being much greater at first and rapidly falling away. The meaning of these results appears to be that, in the example quoted, the actual discrepancy between what the *scale reading indicates as the load* on a specimen and the *true load* is not likely to be greater than 1 per cent., except at the very lowest loads—and, in most cases, it will probably be a good deal below 1 per cent. As in most commercial tests of iron and steel the maximum load does not fall below 15 tons, the accuracy of the machine would appear to be sufficient. The accuracy as here determined takes no account of the individual errors which go to make up the total, but simply gives the relation between the test-load and the scale readings. Tests of this kind give results which are, in a manner, also measures of sensitiveness.

A more usual way of determining sensitiveness is to apply a test-load to the machine, adjust the poise (if it be a lever machine), and add small weights to the test-load until a movement of the weighing-lever indicates that there is a difference in the load on the machine. The added weight, divided by the load on the machine, is then taken as a measure of sensitiveness. There is a certain degree of indefiniteness about this method, in so far as the extent to which the weighing-lever is moved is not usually included in the definition as it obviously should be. Similar instances of calibration tests for accuracy and sensitiveness are quoted by various authorities, notably by Martens, of Charlottenburg. The following few instances of calibration results will be instructive as showing what results are to be expected from tests of this kind.

Professor Kennedy tested the sensitiveness of a Greenwood and Batley horizontal machine, which had previously been used for some 12,000 tests. He found that at a load of 5,000 lbs. a movement of the weighing lever was detected by addition of

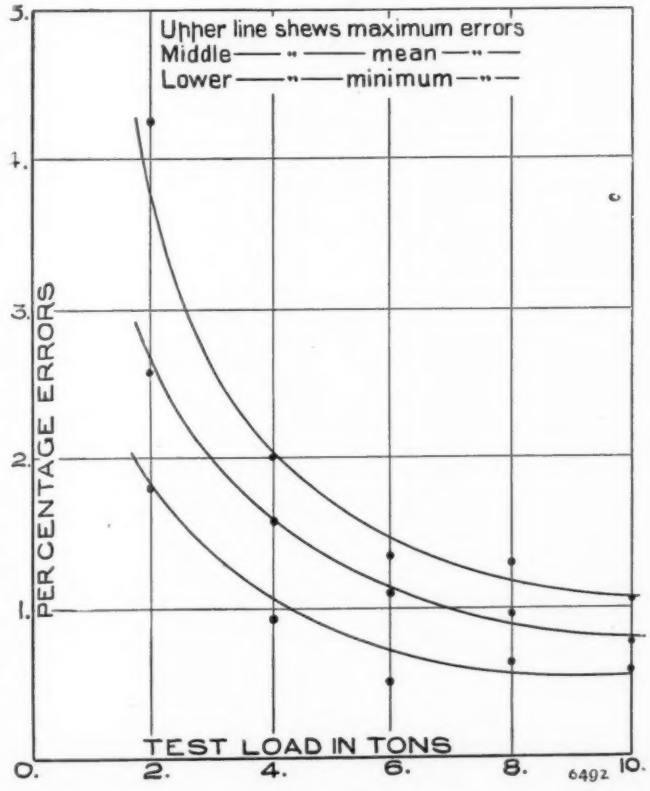


FIG. 2.

a load which was only $\frac{1}{1250}$ of the total load. At 50,000 lbs. load the sensitiveness was much greater, the additional load necessary having fallen to $\frac{1}{10000}$ of the total load.

In a test by Hemming for the accuracy of an Olsen machine, it was found that the accuracy varied from 0·1 per cent. to 0·4 per cent. for a load of 30,000 lbs. On testing the same machine for sensitiveness, Mr. Hemming found that it required about 0·07 per cent. of the load to give a movement of the weighing-lever of $\frac{1}{8}$ in. It may be mentioned here that the Olsen machine is one largely used in the United States, and depends for its load indications on a system of compound levers.

When testing a 30-ton Amsler-Laffon compression machine (this being an oil-pressure machine with a manometer indicating arrangement), Martens found that the error rarely exceeded 1 per cent. Martens also quotes the case of an hydraulic dynamometer in which he found the error to vary from 3 to 0·6 per cent.; and a Wandlebaurg spring apparatus in which the error was below 0·2 per cent. of the load.

From the test whose details have been quoted, and from the above figures given by various authorities, we are led to the conclusion that in most testing-machines used for commercial purposes an accuracy which gives the error of not more than 1 per cent. of the true load can be depended upon, unless the machine has been subjected to rough usage or is suffering from excessive wear. It should be stated that all the same it is not easy to get an accuracy truer by meter than this. But, although in most cases an error of not more than 1 per cent. in a testing machine may reasonably be expected, it must be remembered that a degree of accuracy much in excess of this is rare.

Precision of Testing Machines.

The actual precision, or the fineness of the scale readings, is usually in excess of the attainable accuracy. Most machines are graduated to from 0·010 to 0·005 ton —that is to say, to from about 22 lbs. to 11 lbs. Taking a 1-sq.-in. bar again, with a tensile strength of 30 tons per sq. in., 11 lbs. in 70,000 would be $\frac{1}{6800}$, or far in excess of the actual accuracy attainable. It is perhaps safer to say that, allowing for errors in graduation and errors in reading, loads are more usually read to within 50 lbs., or about 0·07 per cent., still well within the 1 per cent. accuracy of the machine.

Accuracy in Determining the Area of Cross-section.

The next cause of inaccuracy in ascertaining tensile stresses is to be found in the measurements of the size of test-bar. In most cases these measurements are made with a pair of vernier or micrometer calipers, reading to one-thousandth of an inch. Where the bar has been machined measurements can be made to this degree of precision, but where the scale has been left on the bar measurement is of necessity much coarser. To see exactly what an error in this direction may mean, let us suppose the area of the bar is 1 sq. in. and the maximum stress is 30 tons per sq. in.: an error of $\frac{1}{1000}$ in. in linear measurement would mean $\frac{1}{500}$ sq. in. error in area, or a difference in stress of 240 lbs., or $\frac{1}{5}$ of 1 per cent. Of course the smaller the bar the greater the percentage of error. It is probable that, as a rule, in commercial testing this degree of accuracy is not often reached.

Reporting Yield-Point and Maximum Stress.

In view of what has just been said about the accuracy of testing machines and measuring appliances in determining the loads and dimensions of test pieces, it would seem to be unnecessary to report a stress to anything more precise than the nearest 100 lbs. One-tenth of a ton is, roughly, 200 lbs., and one-hundredth of a ton is similarly 20 lbs., so that it will be abundantly sufficient if the results of test stresses are given to the second place of decimals. This means that in the case of the more ordinary tests of steel the result is given to within 0·04 per cent. of itself. In this way the reporting is well within the possible accuracy without being carried to too great a degree of refinement.

Reduction in Area and Elongation.

It is difficult to measure the final dimensions of a test-bar at the point of fracture to much nearer than 0·005 ins. In the case of steel, with a reduction in area of 50 per cent., an error of 0·005 ins. in measuring the diameter at fracture of a turned bar having a section of 0·5 sq. in. would mean an error in the final result of 1 per cent., so that with this rather large possibility of error it would seem quite sufficient to give the reduction in area to the nearest first decimal place.

In the case of elongation the possibility of accuracy is much greater. Measurements of elongation can easily be made to within 0·02 ins., and on a specimen whose measured length is 2 ins. this would mean that the elongation can be known to within 1 per cent. If the elongation be 20 per cent. on the 2 ins., this degree of accuracy will correspond to 0·2 in the result, so that the results may be given to the nearest first decimal place. Where the gauge-length is greater the precision becomes greater, but the writer thinks it quite sufficiently near to report elongations in all cases to the nearest first decimal place, and has invariably followed this practice.

Conclusion.

The writer hopes the foregoing remarks will offer a few suggestions to those engineers who have either to carry out testing operations or have to interpret the results of such operations in the course of their daily work. The intention has been chiefly to make the article in this way suggestive, and to emphasise the fact that there are very definite limits imposed on the degrees of accuracy attainable in the various testing operations. In dealing with test results these limits should be present in the mind of the engineer who has to interpret their meaning, and he will then fail to be misled by figures which profess a degree of accuracy not possible of attainment. And, again, knowing something of these matters, he will appreciate the fact that a good testing machine may be relied upon to yield results whose degree of accuracy may be far in excess of actual requirements, and certainly beyond the differences which are always found to occur in specimens of what is apparently the same material. The last point which need be mentioned is the necessity in all cases of commercial testing not only of knowing how to use a testing machine and carry out tests successfully, but, at the same time, of having means provided for checking the readings of the machine, so that the operator may know the machine he is using, as to its capabilities and accuracy, and at the same time be able to feel confidence in the results he arrives at.

Fire-Resisting Construction.

By W. N. TWELVETREES, M.I.Mech.E.

It is an unfortunate circumstance that the general public and the owners of buildings still attach too little importance to fire-resisting construction. Owing to the admirable services rendered by the fire brigades of our large cities, and especially by the London Fire Brigade, extensive conflagrations are of rare occurrence. Every year, however, fires take place, many being attributable to the improper use of combustible building-materials, while many others are due to the accidental ignition of tenants' goods, fixtures, or furniture, leading to the destruction of the improperly constructed buildings in which such property is placed.

In spite of the lessons taught by repeated fires, the large majority of property owners persist in adherence to obsolete methods of building construction; and even after fires which should teach wisdom, many of them rebuild their premises in the old-fashioned way, as if their object were to invite further disaster.

Taking the community as a whole, it is quite certain that the capital expenditure saved by the avoidance of fire-resisting methods is counterbalanced by the cost of rebuilding structures damaged or entirely destroyed. The outlay does not fall upon the insurance companies, as some people vainly imagine, as the necessary funds are provided out of the premiums paid by the public themselves, who also have to pay for maintaining fire brigades on a much more extensive scale than would otherwise be necessary.

Considering individual members of the community, it must be admitted that many of them are singularly fortunate in enjoying immunity from fires; and it is probable that a spirit of cheerful optimism is largely responsible for the disregard still evidenced for fire-resisting construction.

Indeed, there exists something more than mere disregard; for, if we may judge by comments which appeared in the daily press on the recent conflagrations in Baltimore and Rochester, U.S.A., there is a genuine contempt for fire-resisting construction. From references of the kind it might be inferred by the uninitiated that the most modern American building-methods were almost responsible for the wide extent of the disasters in those two cities. No credence should be attached to statements implying that so-called fireproof buildings were swept away by the devouring flames as if they were built of matchwood. The average newspaper reporter, like the artist, has such an eye for picturesque effect that he cannot reproduce things exactly as they exist in fact. It is all very well to observe nature through the eye of the artist, but embellishment is not desirable in newspaper reports professing to record actual facts.

Our present object is not to offer a detailed account of the Baltimore fire, but as a preface to what follows it may be useful to state very briefly the character of the buildings destroyed in that city and the general lessons taught by the fire.

In the first place it may be remarked that the fire, which commenced on February 7th, 1904, and burned for some thirty hours, covered a site which may be divided into two parts: (1) an area about $\frac{3}{4}$ mile by $\frac{1}{4}$ mile, on which the buildings consisted chiefly of offices and other business premises; and (2) an area of about 40 acres occupied by wharves and warehouses.

Few of the buildings were of more than five or six storeys in height. Nearly all of them had brick walls of the self-supporting type, carrying the floor-beams. About 80 per cent. of the buildings had timber floors and roofs, and a few only were provided with steel beams, some carried on steel or cast-iron columns and others on the brick walls. It will be seen, therefore, that the system of construction was very similar to that used at the present time in this country.

In the entire district there were not

more than about a dozen tall skeleton buildings with fire-protected framework, and of these one was sixteen stories high, the others not exceeding twelve stories in height.

In order that a correct view may be obtained of the effects caused by the fire, the structures should be considered in three categories, namely:—

I. Old-fashioned buildings of moderate height with outer walls of brick or stone, generally designed without any regard to fire prevention and having combustible interior details, fittings, and fixtures. Some buildings in this class, however, had iron window-shutters and automatic sprinklers.

II. Modern buildings, of the type improperly termed "fireproof."

III. Modern buildings of similar type to that in II., but so superior in design and construction that they successfully resisted the flames and heat.

A most significant fact, and one to which we direct the particular attention of our readers, is that all buildings coming within the category I. were totally destroyed. Mr. Ashford, the State Inspector of Buildings of Columbia, states that they were so completely wrecked that nothing remained of them beyond heaps of brick. In some buildings of this class which were provided with sprinkler-tanks, the supports were burned away, and the fall of the tanks aided the flames in the work of destruction. In others, which had unprotected steel-beams and columns, the metal collapsed, and was curled up into strange and unrecognisable forms. Very few of the steel window-shutters were of practical service, most of them being of very thin sheet-metal, offering little or no resistance to the flames. The importance of shutters is evidenced by the fact that in most buildings of this class the windows were broken by the heat, so that the wooden window-frames were rapidly set on fire, followed by the whole interior of the buildings. In other cases fire was communicated through the combustible roof-construction.

If these buildings had been furnished with fire-resisting window-shutters and roofs, it is probable that the progress of the conflagration would have been comparatively small. This is another point to which particular attention should be paid by the owners of combustible buildings in this country, for by a comparatively small outlay a very great measure of protection could be secured.

Turning now to buildings in category II., it may be remarked that, although few of them suffered material injury, the window-glass was destroyed, the wooden window-frames were burned, and all interior woodwork consumed, together with the whole contents of the buildings. The main walls, protected framework, and floors were generally uninjured, but thin partitions in some cases suffered damage. Windows were the vulnerable points throughout, and it is clear that so-called fire-proof buildings will not protect their contents if the windows are left unguarded.

Concerning the four buildings belonging to category III., we append the following notes:—

O'Neill's dry-goods store, which was very much exposed and surrounded by blazing buildings, withstood the fire, and none of its contents was injured. This happy result is attributed to the fact that every window was protected by a water-curtain, automatically started on the approach of the fire.

The Safe Deposit and Trust Building, standing in the path of the fiercest fire, was preserved by the internal steel-shutters, $\frac{1}{4}$ in. thick. The only damage done inside the building was the discoloration of decorations near the windows, and the destruction of an office-table by the ignition of some paint accidentally spilled upon it by some painters who had been at work before the fire broke out. This building had an armoured-glass skylight which successfully resisted external flames and heat. It may be mentioned that this skylight was at one time literally covered with blazing coals, and that fully 5,000 bricks that had fallen red-hot on the roof were afterwards removed.

The new power-house of the United

Railways was of brick with steel and slate roof, copper-covered window-sashes, doors, etc., and armoured glazing. This building resisted the flames and preserved its contents from injury, while the older power-house adjoining was completely wrecked.

The fourth building which resisted attack was the Court House. This is of massive masonry, but the fire was only kept out by the incessant efforts of firemen, who maintained several streams of water against adjoining buildings. Therefore the Court House cannot be regarded as a fire-resisting building, as it would certainly have suffered if left to itself.

The most important conclusion to be drawn from the Baltimore fire is, that the most elaborate system of fire-resisting construction will not suffice to save the contents of a building if the windows are left unguarded.

Armoured-glazing is most desirable, and stout window-shutters or water-curtains are indispensable.

The fire also presents other useful lessons, which our readers may formulate for themselves from the notes following :—

Brick.—Outside brick-walls in most of the fire-proof buildings remained in fair condition, but brick above granite-walls was badly damaged in several buildings. Facing brick on outer walls was generally found to have been detached in patches. In cases where steelwork was protected by brick, it suffered comparatively little injury. Generally, it was proved that brick withstood the fire much better than stone.

Stone.—This class of material did not show particularly satisfactory results. The outer surface of granite walls was wasted away 6 ins. deep in some buildings. Some massive granite columns in the Equitable and Calvert buildings were almost entirely destroyed. Other building-stones used in walls were found to have peeled off in sheets and flakes, while stone mullions and lintels were very much broken.

Concrete. — Concrete-construction, as proved by the United States Fidelity and Guaranty Building, endured the fire practically uninjured. This building was the only one that remained standing in the block where it was situated.

Terra Cotta. — Partitions of this material stood well, but thin partitions of tile, of expanded metal and plaster, were destroyed in the Equitable and Calvert buildings and elsewhere. Terra-cotta guards, round columns, and beams remained intact as a general rule. Hard-burned fireclay and porous terra-cotta, floor arches, and column and beam guards withstood the fire best, but terra-cotta mullions and lintels were much broken.

Cast-iron. — This material suffered severely, mullions being very badly buckled, stairs being completely wrecked; and it was also observed that many of the cast-iron frames used for doors and windows were permanently augmented in volume—a phenomenon which has hitherto escaped the attention of most structural engineers.

Steel. — While unguarded steel is extremely undesirable when employed in the form of columns and beams, the use of steel window-shutters and of steel doors is proved by the Baltimore fire to be of the utmost value.

When adequately protected by the best modern system of fire-resisting construction, steel columns, beams, and the steel framework of buildings were found to have been quite uninjured by the flames and heat.

From the foregoing considerations it is abundantly evident that fire-resisting construction has been amply justified by the Baltimore fire. So far as this country is concerned, there is no excuse for the perpetuation of combustible buildings, as fire-resisting materials of every description are now readily obtainable for the erection and construction of incombustible and fire-resisting walls, columns, beams, floors, partitions, ceilings, roofs, and interior fittings of every kind.

Moreover, there are at the disposal of the designer fire-resisting doors and shutters, improved systems of glazing, automatic sprinklers, and numerous other appliances and devices, which tend most materially to minimise unnecessary fire-risks.

It is of little use to adopt even the most efficient fire-resisting materials for the construction of floors and walls if

other details of a building are liable to combustion or injury by flame and heat. Our object in a succeeding article will therefore be to point out the materials and means available for securing adequate protection for every part of a building, and to furnish data that may be of service to our readers.

(To be concluded.)

CORROSION IN STEAM BOILERS.

By H. C. STANDAGE.

THE influences tending to shorten the life of a steam boiler are both chemical and physical. Of the first kind, chemical, we have the action by corrosion in the rusting of iron, the "pitting" of iron, and the erosion of it by the chemical action of various metallic salts in the feed-water. Of the physical cause we have the damaging action of thick incrustation of scale formed by the deposition of calcic and other salts found in the feed-water. Such incrustations are objectionable in more than one way—viz. by increasing the wear and tear of the boiler, by endangering its safety, and by causing injury to the plate by the adherence of oily acids to the incrustations. We also have the chemico-physical cause of the decomposition of the water holding these oily particles by the steam, whereby the hydrogen thus generated becomes absorbed by the iron and thus rendered brittle and readily liable to fracture.

For the clear enunciation of the facts we wish to elucidate, we will consider each of these causes separately and in detail. In the first place, let us get a clear idea of how hard, solid metallic iron becomes converted into soft powdery "rust."

Iron is a metal that is capable of being produced in more than one way, and according to the method of production so does its ultimate composition and qualities depend. Thus we have wrought-iron, cast-iron, ingot-iron, malleable-iron. Essentially, however, the actual composition of the metal is Fe. Other ingredients—impurities generally—are present in small quantities; as, for example, slag in puddled iron; but for our purpose we will consider the metal to be iron (Fe) only. Now, iron has a very great affinity for oxygen, so much so that it is capable of being oxidised under more than one condition, with the formation of more than one oxide. To wit, we have black oxide (FeO or Fe_2O_2, ferrous oxide), we have the red oxide (*i.e.*, sesquioxide, Fe_2O_3, called also di-ferric trioxide), we have the magnetic oxide Fe_3O_4 (tri-ferric tetroxide), and a variety of ferroso-ferric oxides which are symbolically expressed by the general formula $Fe_nO_n + 1$. Besides being so ready to associate itself with oxygen, iron also readily combines with water in the form of moisture (H_2O), and as a consequence there is more than one hydrated oxide of iron formed by such union, the actual composition being determined by the amount of water combined. The colour of such hydrated oxide varies from brown to red, according to the proportions of the components, the hydrate exhibiting the deepest (reddish or brownish) colour, being the hydrate in which the least amount of water is present. Now, all these hydrated oxides of iron are pulverulent bodies which readily break up into powder by rubbing between the fingers; they are what is commonly called iron rust. Let us now note how such "rusting" is generated. The essential conditions for metallic iron to become converted into hydrated oxide of iron (common "rust") are these: Moisture must be in contact with the iron inter-

mittently; that is, iron which is kept continuously immersed in water will not very readily oxidise provided the water be pure; but water of any kind, pure or impure, will cause metallic iron to rust if the water be in contact with the iron now and again.

It is generally supposed that the presence of carbon dioxide (CO_2) increases the rapidity of the oxidising of iron; but the presence of this gas is not absolutely essential, however, as there is always a small quantity of CO_2 in the iron, and always more or less of it in the feed-water of boilers. We will consider that element as always being present: thus we have as the necessary agents generating rust in iron:—

Iron	Fe.
Water	H_2O
Carbon Dioxide ...	CO_2

Consequently, we can consider that the following equation expresses the chemical changes that occur in the production of rust:—

First Stage—

Fe	+	H_2O	+	CO_2	=	$FeCO_3$	+	H_2
Iron.		Water.		Carbon Dioxide.		Carbonate of Iron.		Hydrogen.

Second Stage—

$2FeCO_3 + 3H_2O$	+	O	=	$Fe_2(OH)_6$	+	$2CO_2$
Carbonate of Iron. Water.		Oxygen.		Hydrated Oxide of Iron, *i.e.*, "Rust."		Carbon Dioxide.

From the above reaction it will be noted that the CO_2 is always present in both stages, and therefore a small quantity of it is sufficient to set up a continual oxidation in indefinitely large amounts of iron.

Now the iron rust which is formed is not always so simple in composition as represented by the formula $Fe_2(OH)_6$ (*i.e.*, pure hydrated ferric oxide), but it, in fact, contains hydrated ferrous oxide, consequently common rust is a ferroso-ferric oxide.

If we consider the rusting of iron, in which CO_2 is an agent, we note that—

$$2Fe + 3H_2O = Fe_2(OH)_6.$$

But as the $Fe_2(OH)_6$ is very hygroscopic, it will in time absorb a fresh supply of water from the air, and consequently allow a fresh quantity of metallic iron to become oxidised—the iron rust, in fact, acts as a carrier of oxygen, thus the chemical process of rusting is a catalytic one, and proceeds, when once initiated, until all the solid metal has become converted into soft pulverulent "rust." Iron which contains carbon rapidly oxidises; the rate of oxidation being quicker in proportion to the quantity of carbon present, the more carbon the quicker the oxidation.

It is not always necessary that the action of moisture should be intermittent, because when once the rusting is begun, it will proceed continuously, as already mentioned, and as the following example proves. The writer placed an ordinary carpenter's saw on a shelf near a bottle containing ammonia. Now just where the neck of the bottle touched the blade of the saw a series of minute specks of iron rust appeared in the course of a few days, such spots having been caused by the escape of ammonia fumes through the cork of the bottle (in only very minute quantities, however), and these fumes, having collected moisture from the air, eventually acted on the steel blade and set up corrosion as above stated. The writer determined to carefully watch the development of the corrosion, and, to do so, allowed the saw blade to remain in exactly the same position as he found it for a few days, but the bottle of ammonia was removed out of the sphere of influence. On again inspecting the spots of rust, they were much larger in size, some of them quite $\frac{1}{8}$th of an inch in diameter, and others coalesced into a mass of brown-red rust. When examined under a magnifying glass, the separate spots were found to be little heaps of iron rust surrounding a deep brown shining spot in the centre. This spot appeared to be in a moist condition, and, therefore, it is safe to assume that it was this precise spot which was imbibing moisture and oxygen from the air, and as the corrosion of the iron continued, the iron which had become fully oxidised was left outside the central spot in a little heap of dry powder, while the centre of the spot was exerting an erosive action on the metal. To test

the best means of arresting the corrosion of the iron, the writer rubbed a portion of the iron rust spots over with paraffin oil and allowed the remainder of the spots to continue their corroding action. At the end of several weeks, those spots which had been thus allowed to continue their corrosion had penetrated the surface of the saw blade to such a depth that it was perceptible to the naked eye. The whole of the rust spots were then smeared over with paraffin oil, and the saw blade left in its original position; but after a further few weeks no new spot of rust occurred anywhere on the surface, and those which had been there, after being smeared with the paraffin oil, did not exhibit any further signs of erosion of the iron.

From these facts, it is quite safe to assume that if the corrosion had been allowed to continue, the saw blade would have been pierced with a series of minute holes where the rust spots had been actively at work. It was noticeable that in the case where the several spots coalesced into one mass, it was only where the centre brown shining spot appeared that the iron was eroded.

There is a very instructive fact to be obtained from the above observation, viz., that a pure hydrocarbon such as paraffin oil or vaseline effectually arrests and prevents further oxidation of the iron. But it is a chemical fact that iron will absorb paraffin oil and partially decompose it; and it is further known that iron which has become impregnated with paraffin oil will exude occluded hydrogen as the oil dries. There is a danger that if a quantity of paraffin oil were kept continuously in contact with the iron that metal would eventually deteriorate in quality and become brittle, owing to the continual presence of hydrogen amongst the fibres of the iron; moreover, this hydrogen might combine with oxygen from the air, and thus, by setting up internal corrosion of the iron, cause the metal to crumble to pieces, or be consumed much in the same way that spongy platinum ignites and is consumed when placed in a stream of oxygen.

The following exhibits the constituents and their proportions in iron rust :—

	Per cent.
Moisture	11·77
Siliccous matter	3·33
Sesquioxide of Iron (Fe_2O_3) ...	66·82
Oxide of Iron (Fe')	3·99
Calcic Oxide (CaO)	0·76
Magnesic Oxide	trace
Copper Oxide (CuO)...	trace
Combined water and loss	13·33
	100·00

The formation of iron rust, however, is not always due to the presence of moisture only. It may be set up by galvanic action, but in any case moisture, or at least moist hydrogen, must be present.

For example, tin is electro-positive to iron; that means that if tin and iron be brought into contact and an electric current be passed through the two metals, the tin would set up decomposition of the iron. Now in the case of zinc and iron the reverse of the above is the case, consequently if these two metals form the electrodes then the zinc will be decomposed and deposited on the iron.

The above two facts explain how it is that, when the tin wears off at any part of a piece of tinned iron, the iron becomes rapidly converted into rust at the exposed part, such rust originating round the exposed edges of the layer of tin and proceeding most rapidly there because the edges of the tin surrounding the exposed portion of the iron forms a galvanic couple with the latter metal. In the case of galvanized iron, *i.e.*, iron coated with a layer of zinc, the attachment of the latter to the iron is a permanent one, because, should any of the zinc become scraped off the iron, the galvanic action that would be set up by moisture acting on the exposed portion of the iron would tend to cover the iron with zinc from the portions of zinc not scraped away. In other words, it would be practically impossible for a globule of water to insert itself between the iron and the zinc layer at any exposed iron spot owing to the zinc being electro-positive to the iron. This explanation only refers to the edges of the exposed spot of iron; if such spot of iron be fairly large, and in contact with moisture, then the water will set up corrosion of the iron in the centre of the

exposed spot, any galvanic couple that is formed thereby occurring round the edges of the zinc and the exposed iron.

Another cause of corrosion or rusting of iron is due to the juxtaposition of two different pieces of iron of different kinds or makes, such difference in make rendering them a galvanic couple, which will increase the rate of corrosion owing to iron being but imperfectly homogeneous. Local rusting is thus often set up with the metal being in contact with any other metal, for example, the slag in wrought-iron is often unevenly distributed, and the loose porous places caused by the presence of the slag are good starting points for "pitting." The manganese in ingot iron may be irregularly dispersed therein, and pitting may result from such circumstance; an example in point is the corrosion which occurs in propeller shafts at the parts where they project from their brass sheathing.

As there are so many metals used in the construction of a boiler, it will be as well, before leaving this portion of the subject, to state a few facts concerning the corrosion that occurs in metals other than iron.

The corrosion of copper will not readily occur when exposed to dry air, as this metal is not readily oxidised, but when exposed to moist air, the copper is attacked, basic carbonates of copper being produced, forming a bluish green film. These cupric-formed salts readily attack metallic copper, while the cuprous salts formed serve as carriers of oxygen whereby progressive corrosion is set up much in the same catalytic way as is the case when iron is oxidised. In the presence of air and gas the corrosion is increased, as likewise the progressiveness of same.

If the acid gas possess chlorine as a constituent, or the copper be subjected to the action of a solution of salt (chloride of sodium) in the presence of air, the corrosion is then due to the formation of an oxychloride instead of a basic carbonate. Sea water has a less energetic corrosive action on the copper than it has on iron, and whatever salts of copper are formed by the corrosive process act as a protection against the growth of marine inanimate or animate life, owing to the poisonous nature of such salts. The alloys made from copper in which zinc is a chief ingredient are more easily corroded than the pure copper itself, but alloys in which tin is the chief secondary metal are less corrodible than the copper. Propeller-blades, filter-press plates, and ships' fittings, are usually made of copper aluminium alloys (aluminium bronzes), because such metals are practically non-corrodible by the ordinary atmospheric and saline agencies.

As already mentioned, zinc becomes coated with a plate of oxide or basic carbonate when exposed to moist air, but such oxide or carbonate forms a protective coating to the metal bearing it, but solutions of chlorides or acid gases dissolve such oxide or carbonate coating, and the metal then corrodes. Zinc, if it be in contact with an electro-negative metal, or the solution of a salt of one, such as copper, the zinc is dissolved, a galvanic couple being formed, and the corrosion proceeds at a rapid rate. Chemically pure zinc is practically incorrodible by atmospheric influences, but as commercial zinc is seldom free from lead, it possesses the elements of a galvanic couple in itself. When galvanised iron (*i.e.*, iron covered with zinc) is used for receptacles for alkaline and calcareous waters it does not readily corrode, because the coating of basic carbonates that is produced protects the metal; water, however, that is free from lime, but contains traces of organic acids and nitrates (which suffer reduction to ammonia) attacks zinc, and zinced pipes are unsuitable for this reason, the more so as any exposed iron forms a couple with the zinc and increases its rate of corrosion. As salts of zinc are poisonous, their presence in potable water is objectionable. Alkalies have a solvent action on zinc, and as a consequence the alkalinity of mortar, cement, or even the alkaline salts in bricks, will act destructively on metallic zinc. As regards the corrosion of aluminium, that metal is not readily corroded in the air, but it readily oxidises when amalgamated with mercury or alloyed with antimony, but aluminium

bronze (a mixture of 90 per cent. of Cu and 10 per cent. of Al), and aluminium brass (Cu 63 per cent., Al 3·3 per cent., zinc 33·3 per cent.), are not readily corroded as ordinary brasses or bronzes.

Having thus considered the cause and formation of "rust" so far as metal is concerned, let us now consider the question as regards the quality or composition of the feed-water used in a boiler. The quality of the water used in a boiler is one of the chief factors tending to shorten the life of the boiler: hard scale is formed from waters containing lime and magnesium salts,* and as a consequence of the formation of such scale the fuel is wasted in raising the water to steam-heat. The boiler-plates are more or less overheated, because this scale is a bad conductor of heat, and as the water cannot therefore come into immediate contact with the iron plates, the latter become overheated, causing bursting and other mishaps. Moreover, the maximum amount of steam raised with a given quantity of fuel is never reached, owing to the presence of this scale. To get a greater quantity of steam the stoker increases the rate of firing, and as the extra quantity of heat which is generated is not perfectly absorbed by the boiler, it goes to waste in the flue gases. An increase of $\frac{3}{16}$-in. thick necessitates the use of 16 per cent. more fuel than clean plates require, while, in the opinion of some engineers, as much as 50 per cent. is wasted with a scale $\frac{1}{4}$-in. thick, and one $\frac{1}{2}$-in. thick causes a wasting of 150 per cent. of fuel.

In a recent paper before the Institution of Mechanical Engineers, entitled "An Inquiry into the Working of Various Water-Softeners," the authors, Messrs. Stromeyer and Baron, arrived at the conclusion that even a thick coating of scale did not materially affect the efficiency of the boiler, but only interferes with the transmission of heat, if that heat-source be of equal temperature over the whole surface. The following table was given, from which it will be seen that the addition of scale $\frac{1}{8}$-in. in thickness only reduces the transmitted heat by 11·6 per cent., whereas when the gases reach the end to where the value of heating-surface to fuel

TEMPERATURE DISTRIBUTION IN A BOILER.

Square feet of heating surface per lb. of fuel per hour	0	¼	½	1	2	4	8
BOILER WITH PLATES FREE FROM SCALE.							
Flame and flue temperature, degs. Fahr. ...	3,000	2,421	1,961	1,335	728	426	381
Maximum plate ,, ,, ,, ...	400	396	392	387	383	381	380
Total heat transmitted, per cent.	0	19·8	35·6	57·0	77·8	89·2	89·7
BOILER WITH SCALE ¼-IN. THICK.							
Flame and flue temperature, degs. Fahr. ...	3,000	2,484	2,070	1,471	835	459	384
Maximum plate ,, ,, ,, ...	691	630	581	510	434	389	382
Total heat transmitted, per cent.	0	17·5	31·8	31·8	74·2	87·0	89·5

* The inorganic substances usually found in water tending to form a scale are: carbonate of lime, sulphate of lime, sulphate of magnesia, silica, oxides of iron and alumina, and suspended matter. Those causing corrosion are: sulphuric, hydrochloric, carbonic, acetic, and tannic acids. Sulphate of iron and chloride of magnesia not only form scale, but set up corrosion. The carbonates, sulphates and chlorides of sodium, and sometimes potassium, are found, especially sodium chloride. These substances cause no particular harm, except when they are present beyond a certain amount, in which case foaming will result. When a water which contains a part or all of these impurities is heated to 212 degs. Fahr., and is boiled for some time, the carbonates of lime and magnesia are precipitated; but it requires a temperature of about 300 degs. Fahr. (or steam at 70 lbs. pressure)

is 4 per cent., the total reduction falls to only 2·5 per cent. The table, however, shows that net scale $\frac{1}{8}$-in. in thickness raises the temperature of the furnace-plate in this case to nearly 300 degs. Fahr., a figure sufficiently high to almost cause collapse.

Engineers, however, seem to be agreed that a water which gives a very slight incrustation of calcic-carbonate or sulphate is more beneficial than otherwise, because such scale prevents the metal becoming corroded by any of the many sources which would otherwise act on the metal destructively. Certain calcareous salts, in the presence of saline waters, form an incrustation which is as baneful as a formation arising from calcareous waters proper.

For example, chloride of magnesium, when present in saline waters, exerts a corrosive effect on the boiler in parts that are not protected by a coat of scale—such as above the water line. If free acid be present in the water—such as brine water—the metal will be seriously corroded. Such water should not be used unless the free acid has been previously neutralised by treating the water with some material that will combine with the free acid and thus free the water from its presence. As an example of the corrosive effects of water containing free acid and salts of minerals which are reducible more or less by iron—as, for example, copper and iron in the ferrous state—the action of the acid on the copper salt and the boiler-plates would be to set up a galvanic action whereby the copper salt would be resolved into metallic copper, which would become deposited on the iron plate, but for every particle of metallic copper so eliminated from its salts there would be an equivalent quantity of iron carried away from the plate, and, as a consequence, the iron plate would gradually become thinner and thinner. Thus, suppose that the copper salt is sulphate of copper ($CuSO_4$) and the acid is sulphuric, hydrochloric, or nitric acid, then there would be a double decomposition, which would be greatly increased in intensity by the acid, *e.g.*,

$$CuSO_4 + Fe = FeSO_4 + Cu.$$

In the presence of an acid the $CuSO_4$ would become decomposed and Cu set free, *e.g.*,

$$CuSO_4 + 2HCl = CuCl_2 + H_2SO_4, \text{ and}$$
$$H_2SO_4 + Fe = FeSO_4 + H_2 \text{ (free).}$$

But this free H_2 would combine with the chlorine in the copper chloride and set the copper free, *e.g.*,

$$CuCl_2 + H_2 = 2HCl + Cu.$$

The above formulæ mean this: the SO_4 of the copper sulphate would unite with the H_2 of the acid and set the Cu free, and also the Cl from the acid; they would combine and form copper chloride, then the sulphuric acid (H_2SO_4) that is then formed would decompose the iron, forming sulphate of iron and setting free the hydrogen; the free hydrogen would combine with the chlorine in the copper chloride and set free the copper, and as a consequence the metallic copper would attach itself to the iron plates, which would then become coated with a layer of metallic copper, this copper coating, however, would not be a protective one, but it would form with the iron an iron copper couple, of which the iron would be the attackable metal.

Again, if chloride of iron instead of sulphate of copper be present in the feed water, then the iron plates suffer a similar thinning, part of the iron being dissolved off and the ferric salt becoming converted into ferrous salt, *e.g.*,

$$FeCl_2 + 2H_2SO_4 + Fe = 2FeSO_4 + 2HCl + 2H.$$

Now if free oxygen also be present in such a water as the last, then the ferrous salt which is formed will become further

to precipitate the sulphates of lime and magnesia. The continual evaporation of the water concentrates these impurities, until finally the point of saturation is reached. Then the bulk of the more soluble impurities will be precipitated, together with the less soluble carbonates, sulphates, and even chlorides. This deposit of scale forms wherever the water comes in contact with the hot metal. The deposit is piled up in thin layers of iron, silica, lime, and magnesia, and is generally the thickest where the least amount of steam is generated. The carbonates of lime and magnesia are non-conductors of heat, having relative values of ·67 and ·76 (felt or wool being 1·00). It is claimed the conducting power of iron for heat is about thirty times that of saturated scale.—Cf. a paper by J. C. Greth, *Proc. Engs. Soc. W. Pennsylvania, Vol. XX, No. 1.*

oxidised and thus act as a carrier of oxygen to the iron boiler-plates, and so oxidise (*i.e.*, corrode) the latter metal.

In water that is obtained by draining bogs, marshes, etc., there is a lot of organic (peaty) matter present which is usually more or less acid or develops gases by the decomposition of the peaty matter. As such waters are soft, *i.e.*, free from lime and other mineral salts, such acids have free play on the iron of the boiler because there is no protective scale to prevent the free attack of such gases. Moreover, such peaty waters naturally possess a larger quantity of oxygen dissolved in them, the presence of which increases the activity of the gases and acids in the water, consequently peaty waters will be very active in corroding the boiler plates if they have not a layer of scale on them ; such a layer would limit the activities of the above-mentioned waters.

One material fact should be mentioned, viz., that the part of the boiler-plate which suffers corrosion most is just at the water line ; this is so because as the water becomes heated the dissolved gases—they are not chemically combined with the water—being mechanically suspended therein, will be expelled by the convection currents that rise to the surface. Many of these gaseous bubbles will rise up the sides of the plates, and if there be any rigidity of surface which will arrest the rising of the bubbles, such bubbles of gas will cling to the surface of the plate and thereby cause "pitting"—provided a series of gaseous bubbles are arrested in precisely the same spot.

The reason that the water-line becomes corroded more than the iron above the water or that beneath it is this, the iron at the water-line is continually wet or moist, but not covered with more than a thin film of water—it occupies, in fact, just such a condition as a piece of iron on which water has been spilled and exposed to the air—whence a rapid rusting of the iron will occur, particularly so as the gas bubbles, when they rise to the surface of the water, will cling to the wet sides of the plates. Now, if any of these bubbles of gas be hydrogen, such gas will become more or less absorbed by the iron, which will in consequence become brittle and liable to sudden fracture.

There is yet another cause of corrosion of the metal plates, viz., the absorption of any fatty or oily matter by the water, such oily matter being derived from the lubricant and carried mostly thence into the working parts of the boiler. At the temperature of steam, decomposition or hydrolysis of the oil or fat will occur, such decomposition being aided by the presence of metallic oxides from the material of the cylinders. The result of such hydrolysis is to separate the oil or fat into its constituent fatty oil acids, and these may be volatilized with the exhaust steam into the condenser of the engine, and thus pass with the fluid water into the boiler.

Now, it is a point worthy of mention that it is only the vegetable oils or animal fats that can suffer this hydrolysis into fatty acids. Mineral (*i.e.*, hydrocarbon) oils do not form any such acids, because the mineral oils are composed of carbon and hydrogen only, which are incapable of forming an acid by themselves, but there is always a possibility of a portion of the mineral oil being distilled over with the steam, in spite of the temperature of the cylinder being below that at which distillation occurs, and may therefore find its way into the boiler. If any mineral oil does find its way into the boiler water, it will be more beneficial than harmful, because the oily globules will attach themselves mechanically to the calcic carbonate and sulphate during the decomposition of the water, and eventually coat the plate with a non-conducting incrustation which will more thoroughly protect the iron plates from contact with the water by reason of the oily character of the incrustation. This is the case when the incrustation is purely calcareous.

In the case of fatty acids finding their way into the boiler, a totally different result occurs, they will form mineral soap with the salts of the various minerals in the water. In the case of calcic salts being present lime soap will be produced, and the deposit of scale will be an oily incrustation of a very badly-conducting

nature. If, however, the water be rendered alkaline by the aid of soda or potash salts (which constitute the basis of most anti-crustor compounds), then the fatty oil acids will combine with the alkali and produce true soap, which will be dissolved in the water as fast as it is formed, comparatively speaking, and as a consequence the steam water will not be pure water, but a solution of soap, and, *ipso facto*, in delicate working parts, such as cylinders, valves, etc., such soap will be resolved into a semi-solid mass, and eventually lead to jamming or priming. Such a result could not occur with a lubricator compounded of mineral oils only. The inference from these facts is that the proper lubricant for a cylinder or valve should be a hydrocarbon one, not a compound of vegetable oils and animal fats.

The characteristic of the deposits of the oily incrustation on the boiler-plates is the overheating to which they become liable owing to the bad conducting nature of the incrustation and thereby sudden collapse of the plates.

The following table shows the composition of such a scale :—

	Per cent.
Calcic Sulphate ($CaSO_4$)	59·11
Calcic Carbonate (CaO_3)	6·07
Magnesium Hydrated Oxide ($Mg(OH)_2$)	11·29
Sesquioxide of Iron (Fe_2O_3)... ... and Sesquioxide of Aluminium (Al_2O_3) and Silicon Dioxide (SiO_2)	2·85
Organic Matter and Oil	19·54
Moisture	1·14
	100·00

Having thus considered the nature of corrosion set up by the feed-water, let us now consider the corrosion which is engendered by the iron itself.

The composition of the iron may not be perfectly homogeneous ; ingot-iron, for example, may have magnesium and sulphur irregularly distributed in it as impurities. The spots which are rich in these impurities will suffer corrosion more rapidly than other parts possibly because of the formation of a galvanic couple between adjacent portions of the plate which are of different composition. In puddled-iron the slag is never evenly distributed throughout the mass, and the places richest in these impurities will be corroded, the mechanical looseness of structure, due to the presence of the slag, often aiding the effect.

It not infrequently happens that particles of iron and copper find their way into the boiler, and these particles are liable to act as centres of corrosion by setting up electrolytic action in which the iron is the metal attacked. This is especially the case when most of the surrounding iron is protected by incrustation, the corrosive action being then localised, consequent on the increasing in current density arising from the restriction of the surface by the larger electrode.

As already mentioned about the escape of gas and air bubbles, such trappings of these bubbles will set up local corrosion. The oxidation and deepening of these spots proceeds by the successive portions of entrapped air. Pitting, however, from local causes other than those arising from the nature of the metal is not common in boilers, because any liquid or gaseous corrosive substance introduced into the boiler tends to be diffused all over the exposed surface by the agitation and circulation of the water and atmosphere in the boiler. An attempt has been often made, and with fair results, to divert corrosive oils in the iron boiler-plates by suspending in the water plates of zinc ; these plates divert attack from the iron to themselves by galvanic action, whereby the tendencies of corrosion of the iron is minimised.

A New Process for the Protection of Iron and Steel from Corrosion.

By SHERARD COWPER-COLES, A.M.Inst.C.E., M.I.E.E.

ZINC has proved the most effective coating for iron and steel ; and hot galvanising, with all its attendant disadvantages, is the process most extensively used for applying the zinc coating. Electro-zincing, or cold galvanising, is used for special classes of work and is extensively used by the Admiralty for giving boiler tubes a thin flashing of zinc for the purpose of detecting flaws and protecting the tubes from corrosion during the time of assembly and inaction.

Works have just been completed for a new process, the point of particular interest about which, is, that iron and steel can be coated with a thin even deposit of zinc at a temperature many hundreds of degrees below the melting point of zinc.

The first step in the process is to free the iron from scale and oxide by any of the well-known methods, such as dipping in an acid solution or sandblasting. The articles to be rendered rustless are then placed in a closed iron receptacle, charged with zinc dust which is heated to a temperature of from 500 degs. to 600 degs. Fahr. for a few hours and allowed to cool ; the drum is then opened and the iron articles removed, when they are found to be coated with a fine homogeneous covering of zinc, the thickness depending on the temperature and the length

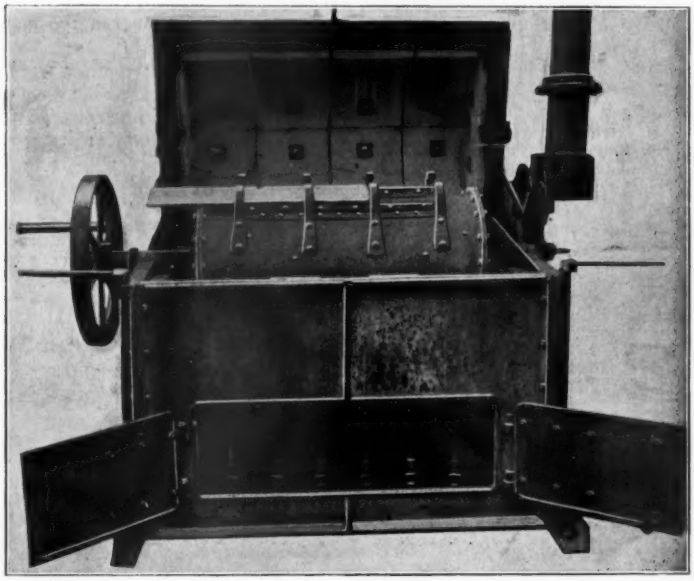


FIG. 1.—VIEW OF FURNACE.

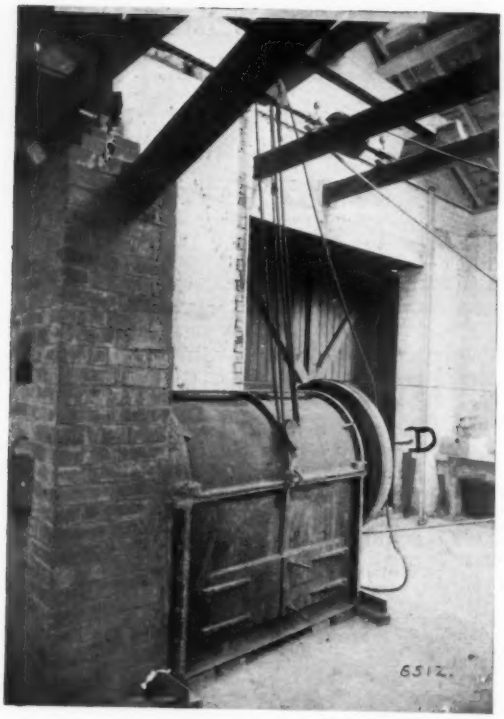


FIG. 2.—VIEW OF DRUM IN POSITION.

of time. It will be observed that the temperature required to bring about this result is about 200 degs. below the melting point of zinc. The low temperature required makes the process cheap as compared to the process of dipping in molten zinc, and has the additional advantage that it does not deteriorate iron or steel of small section to the same extent as hot galvanising. The whole of the zinc is consumed; there is no waste of zinc as in the hot galvanising process. This new process of dry galvanising is not limited to the coating of iron with zinc, it has been successfully applied to coating iron with copper, aluminium, and antimony. It has also been applied to coating various other metals, for instance, aluminium and copper with zinc. Copper and its alloys subjected to this process are case-hardened on the surface, and can be rendered so hard as to turn the edge of a steel tool.

The zinc powder used in the process is the zinc dust of commerce and must not be confused with zinc oxide: it is obtained

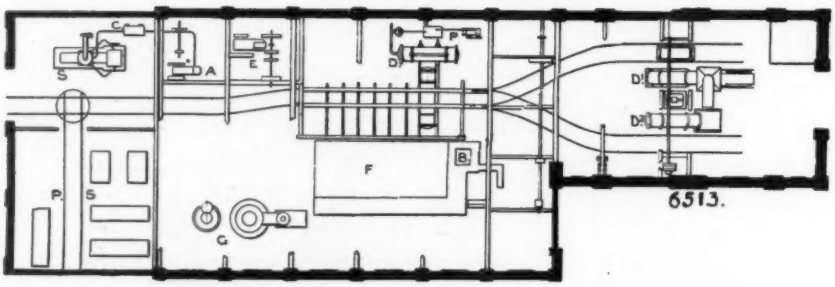


FIG. 3.—PLAN OF SHERARDISING PLANT.

A Air Compressor.
B Chimney Stack.
C Air Tank.
D Drum.
*D*1 Drum (filling position).
*D*2 Ditto (emptying position).
E Gas Engine.
F Furnaces.
G Producer Plant.
P Exhaust Pump.
PS Pickling Shed.
S Sandblast.

during the process of distilling zinc from its ores. Zinc dust at the present time is used for a variety of purposes and can be obtained in any desired quantity. The average price of zinc-dust for the year 1903 was £19 19*s.* per ton, which is slightly below the average price of virgin spelter. The analysis of two samples of zinc-dust, such as are employed in the new process, gave respectively 85 and 85·06 per cent., and 81·86 per cent. metallic zinc. Both samples, when examined under the microscope, seemed to contain small bright metallic beads, unevenly distributed through the dust, and it is probable that this may account for the different percentage given by analysis. One of the peculiar properties of zinc-dust is that it cannot be smelted or reduced to the metallic form under ordinary conditions, even when heated to a very high temperature under considerable pressure. This property is very advantageous for the new process of dry galvanising, as it does away with the risk there might otherwise be of melting the finely-divided zinc by overheating the furnace. The receptacle in which the zinc-dust is placed and heated is preferably air-tight, and the air exhausted, so as to prevent the formation of too much zinc oxide; or, if this is not feasible, it is found advisable to add about 3 per cent. of carbon in a very fine state of division. If the percentage of oxide is allowed to increase beyond certain limits, it is found that the deposits become dull in appearance instead of having a bright metallic lustre, although good deposits of zinc can be obtained from zinc-dust varying considerably in composition. To prevent the iron receptacle in which the process is carried on from becoming thickly coated with zinc, it is found advantageous to coat the inside of the drum with plumbago or blacklead. Articles coated with grease receive as good, if not a better, coating of zinc than those which are free from grease. This fact is of considerable importance, as it enables machine-work, such as bolts, nuts, screws, etc., to be thrown direct, after machining, into the drum without any preparation or cleaning. The articles, when they have been heated in the zinc-dust for the period necessary to obtain the thickness of zinc required, can be removed whilst the zinc-dust is still hot, although the better practice is to allow the zinc-dust to cool to a temperature at which the articles can be readily handled, as the deposit of zinc is whiter and less oxide of zinc is formed. This new process of dry-galvanising offers many facilities and great economy to those manufacturers who have not sufficient work to keep a large bath of molten zinc continuously employed.

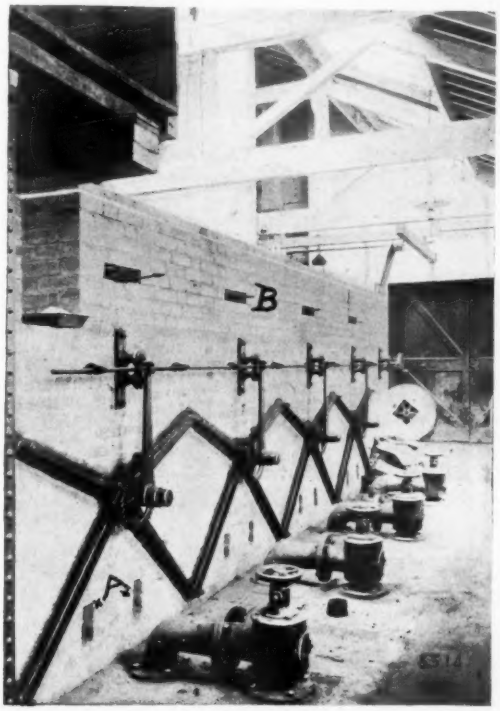


FIG. 4.—METHOD OF HEATING FURNACES BY DOWSON GAS.

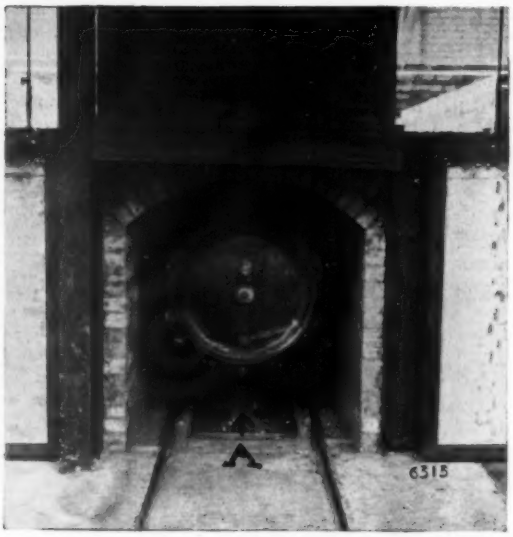


FIG. 5.—FURNACE WITH DRUM IN POSITION.

Articles can be treated at a few hours' notice, starting all cold, as the drums can readily be heated by gas or coke furnaces, the whole operation occupying only a few hours.

A useful type of furnace for small work consists of a closed iron chamber, in the form of a cylinder or polygon, and arranged to be rotated or oscillated about an axis. The chamber is provided with an iron door, either at one end or at the side, depending upon the class of articles to be treated. A side door is found to be the most suitable for small articles, such as bolts, nuts, small castings, etc., and the end-doors for tubes, oblong or cylindrical articles. In the latter case the cylinder is oscillated on its axis; in the former case it is rotated

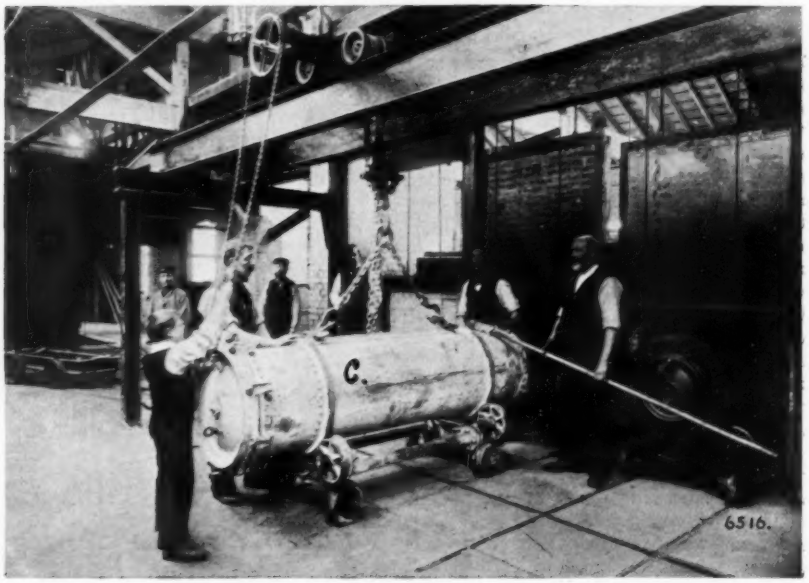


FIG. 6.—DRUM ON FURNACE TRUCK.

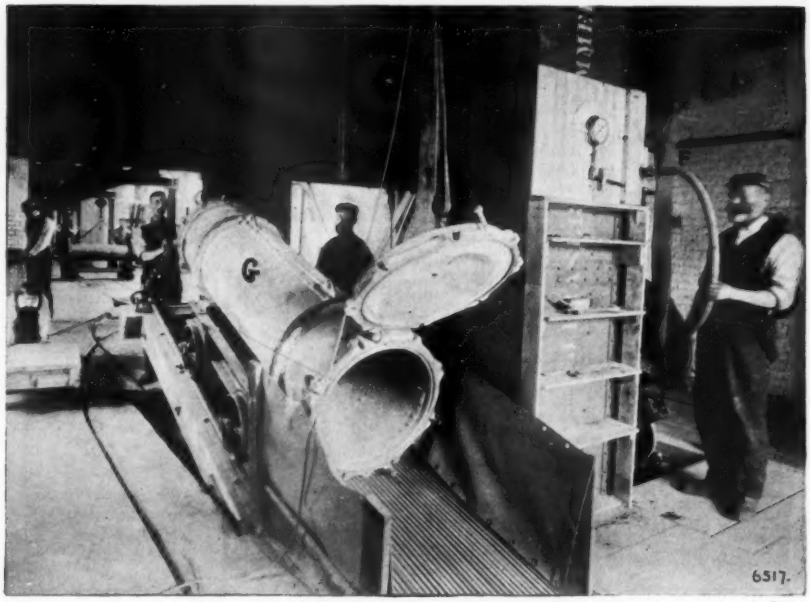


FIG. 7.—DRUMS ON CHARGING AND DISCHARGING PLATFORMS.

and provided with baffle-plates, to ensure the articles under treatment being turned over and thus becoming uniformly coated by bringing all parts into intimate contact with the zinc dust. Fig. 1 shows such a furnace suitable for treating 1 cwt. or 2 cwts. of small articles at a time. One of the trunnions is made hollow, so that a pyrometer can be inserted. Below the furnace is arranged a number of Bunsen gas-burners for heating the drum, and the whole is enclosed in a cast-iron shell lined with fire-brick. The drum can be rotated either by hand intermittently, or continuously by means of a suitable gearing *D*, as shown in Fig. 2, which illustrates a similar construction of drum. The plant required for dealing with all classes of work must of necessity be modified to suit the different classes of work: for instance, if it is required to treat an expanding-gate or girder, an iron box would be used, which would be kept stationary during the process, the gate being opened to its full extent during the operation. Tubes require a different construction of drum to the drum required for bolts and nuts; wire and sheets also require modified arrangements to enable the work to be handled expeditiously. Fig. 3 shows the general arrangement of a plant which has recently been completed, comprising four furnaces which are capable of taking drums of 8 ft. by 2 ft., with a cubic capacity of 2 tons of material at a charge; the weight of iron capable of being dealt with per charge depending on how close the articles pack. The furnaces are heated by Dowson gas. The gas is led by iron pipes to the back of the furnaces, the supply of gas being controlled by iron cocks, as shown in Fig. 4; the gas is then conducted through brick channels through which the air is drawn through the inlets *A*, the gas being burnt through cast-iron burners *A*, as shown in Fig. 5.

The charging of the drum is effected by running the truck on which the drum is placed on to a table (Fig. 6), one end of

FIG. 8.

FIG. 9.

FIG. 10.

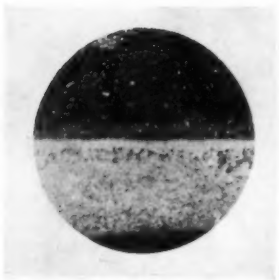


FIG. 11.

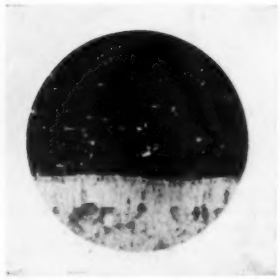


FIG. 12.

which is lowered by means of gearing so as to tilt the other end, into which the zinc-dust is charged from an upper floor by means of a shoot *F*, as shown in Fig. 7. *G* is a drum being discharged over an iron grating, which allows the zinc to fall into a chamber below, from which it is raised by means of a chain elevator to the floor above. When the drum is charged with zinc-dust and the articles to be treated, it is brought into a horizontal position, the air is exhausted, and the truck is run along the lines until it arrives in front of the furnaces. It is then lifted on to a furnace-truck, the object being to effect a saving in the first cost of the furnace, and to save waste of heat. The drum is then pushed into the furnace, the door lowered, and the furnace heated up to the desired temperature. The heat is regulated in accordance with the readings of a thermometer which is placed in a vertical iron tube inside the furnace. When the drum has been in the furnace a sufficient time to give the desired result, the door is then raised and the drum and carriage withdrawn, the drum lifted on to another carriage and run out into an open yard, where it is allowed to cool down to a temperature low enough to admit of easy handling.

The comparison of the surfaces obtained by hot and cold galvanising, and the new process to which the name of Sherardising has been applied, is different in each case, but they can readily be distinguished by anybody conversant with the three processes. In the case of hot galvanising, the surface is spangled, or if not spangled, has the appearance of cast metal. In the case of cold galvanising, the surface is free from spangles, and has a matt, or frosted surface, uniform if the work has been well executed. Sherardising is again

distinctive from the two former processes, the general appearance resembles more that of cold-galvanising than hot-galvanising, but is more lustrous and metallic, and is uniformly distributed over the whole surface, which is not the case with the hot- and cold-galvanising processes. The new process, although similar to cold-galvanising in some respects, is also similar to hot-galvanising in other respects, inasmuch as the zinc alloys with the iron and forms a protective zinc-iron alloy, intermediate between the zinc coating and the underlying metal. Fig. 8 shows a photo-micrograph of hot-galvanising, the line in the centre shows the line of demarcation between the crystal or spangles. Fig. 9 shows zinc electro deposited by the regenerative process from a solution of zinc sulphate, kept in the best working condition by passing the electrolyte through a filter-bed of zinc-dust and coke. The current-density being about 20 amp. per sq. ft. of cathode surface. Fig. 10 shows an iron surface coated with zinc by the new process. In practice Sherardised iron and steel are found to withstand the ordinary corrosive agents galvanised iron is exposed to, to a remarkable degree: even after the apparent removal of all the zinc by filing or abrasion the iron is still non-corrosive. This valuable property is doubtless due to the protective action of the zinc-iron alloy formed on the boundary-line between the iron and zinc, and which is clearly shown on the photo-micrographs Nos. 11 and 12.

As Sherardising is effected at a very much lower temperature than hot galvanising, the temper of steel wire is not reduced as it is in the latter process. A number of steel and iron bolts treated at varying temperatures, when tested for tensile strength, were found to be equal in strength to bolts which had not been Sherardised. The following table gives the results of tests for tensile strength upon four untreated and four treated Sherardised specimens of steel rod:—

Dimensions.	Extension.				On Original Area.				Remarks.
	Area—Sq. Ins.	Reduction of Area at Fracture. %	On 2". %	On 2" at Fracture. %	Elastic Limit (Yields Point).		Maximum Stress.		
					Lbs. per Sq. In.	Tons per Sq. In.	Lbs. per Sq. In.	Tons per Sq. In.	
Untreated steel rod:									
0·276 × 0·277 ...	0·0774	—	1·0	—	70,358	31·41	121,676	54·32	Irregular fracture, broke outside datum points in jaws.
0·274 × 0·274 ...	0·0750	6·6	3·0	—	49,280	22·0	150,796	67·32	Broke outside datum points in jaws.
0·278 × 0·278 ...	0·0772	—	3·5	—	73,987	33·03	149,408	66·70	Irregular fracture, broke outside datum points in jaws.
0·283 × 0·263 ...	0·0758	3·7	3·0	—	69,440	31·00	153,932	68·72	Broke outside datum points in jaws.
Sherardised steel rod:									
0·279 × 0·285 ...	0·0795	19·9	7·0	—	113,545	50·69	156,598	69·91	Steel rods treated.
0·274 × 0·279 ...	0·0754	6·7	4·0	—	102,032	45·55	148,064	66·10	
0·274 × 0·283 ...	0·0775	15·9	6·0	—	Not observable		154,918	69·16	
0·276 × 0·284 ...	0·0783	4·8	3·5	—	108,147	48·28	149,632	66·80	Broke outside datum points in jaws.

The cost of working is less than hot galvanising, the plant is very much cheaper, there is no waste of zinc, no flux required, no dross or skimmings formed, no danger of explosion or breaking of castings and distorting of thin iron-work. Sherardised machine-work does not require refitting, as the coating is evenly distributed. There is no reduction in tensile strength as in the case of hot galvanising, the coating is more uniform and even than that obtained in hot or cold galvanising, the work can be placed direct in the Sherardising drum from the pickling-vat without drying, the process can be worked intermittently without waste, iron can be coated with zinc to any desired thickness. Another advantage of Sherardising, provided sufficient time is given for coating, is that it has the effect of bringing the surface into a more uniform state of tension.

THE WESTINGHOUSE SYSTEM OF MULTIPLE-UNIT TRAIN CONTROL.

IT is now acknowledged by all classes of engineers that electricity offers the only satisfactory solution of the problem of the quicker working of city and suburban railway traffic; and there is no doubt that we are on the eve of a general, though necessarily gradual, conversion of local lines from steam to electric working.

The chief reasons for this are two in number. Firstly, the possibility of quickly building-up or splitting-up trains with one or more motor cars combined with trailer or non-motor cars, just as the density of the traffic requires. Secondly, the high rate of acceleration which is obtained by having a number of pairs of driving wheels distributed along the length of the train.

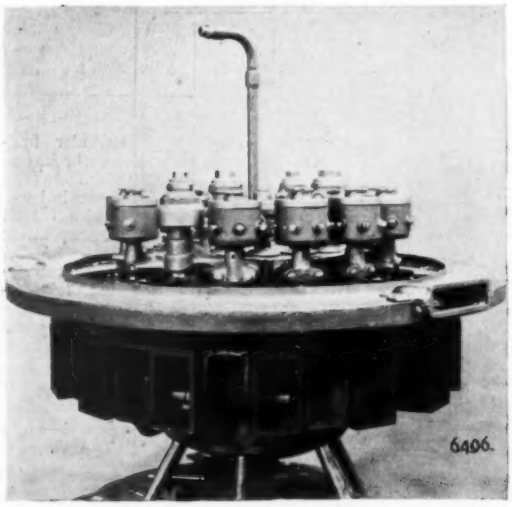


FIG. 1.—TURRET CONTROLLER WITH COVER REMOVED.

Each motor coach may be looked upon as a combination of an electric locomotive and passenger car; but the driver's portion of such a car occupies so little space as to be almost unnoticeable; the motors, controlling gear, and brake gear being conveniently stowed away beneath the car body. As already mentioned, a train may be built up of one or more such driving units interspersed with trailers or non-motor coaches, this constituting the multiple-unit system of electric train working.

One has only to consider the time occupied in getting up speed and in

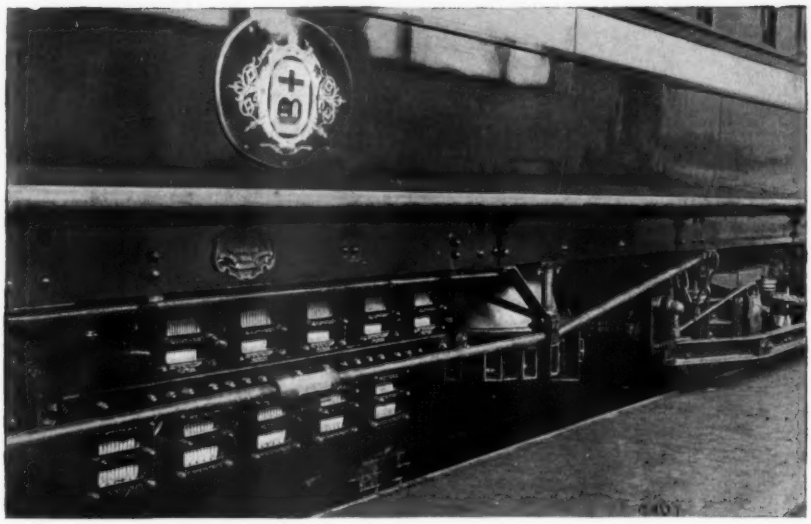


FIG. 2.—EQUIPMENT OF METROPOLITAN RAILWAY CARS, SHOWING POSITION OF TURRET CONTROLLER ON UNDERSIDE OF CAR.

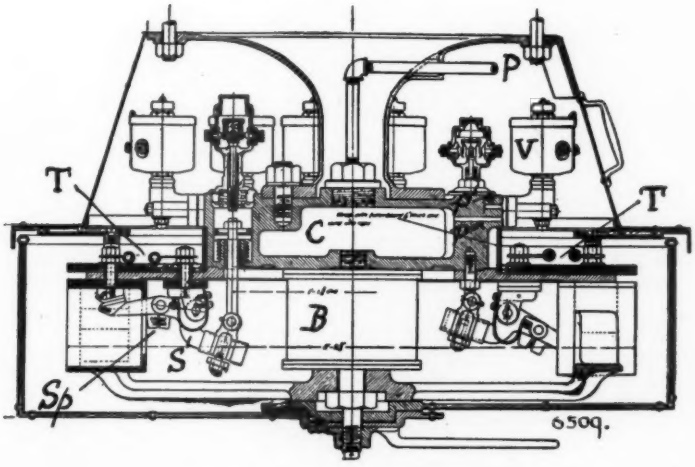


FIG. 3.—PART SECTION OF TURRET CONTROLLER.

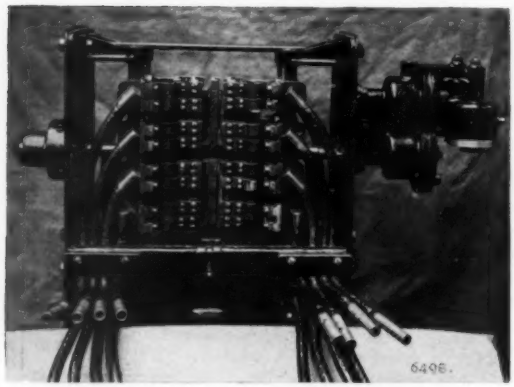


FIG. 4.—INTERIOR OF PNEUMATICALLY-OPERATED REVERSING SWITCH.

slowing down, say on a run through a dozen city or suburban stations, in order to appreciate the vital importance of rapid acceleration and retardation. That rapid acceleration can be obtained much more easily through the distribution of the driving power over many wheels (which is made possible by an efficient and reliable multiple-unit electric system) than through the usual concentration of the driving power in a steam locomotive, must be clear to anyone.

The Brooklyn Heights and the Chicago Elevated Railways in America, the Metropolitan Railway in Paris, and the Mersey Tunnel Railway in England are all equipped on this system, these examples being followed in the electrification of the Metropolitan Railway.

The following descriptions and illustrations refer more particularly to the apparatus with which the cars of the Metropolitan Railway of London are being equipped.

The Westinghouse system has proved highly successful in the United States, and is also in satisfactory operation on the Mersey Railway in this country, which, it will be remembered, was converted to electrical working by the British Westinghouse Company.

For large and heavy cars requiring very powerful motors one of the latest forms of controller is the Westinghouse Turret Controller. This takes its name from the fact that it is turret-shaped. It consists of a number of radially-grouped circuit-breakers or unit-switches, which are closed by air-pistons working against powerful springs which open the switch contacts when the air-pressure is removed. Fig. 1 shows a turret-controller with its cover removed. Fig. 2 illustrates its position on the underside of a motor coach. The fifteen separate circuit-breakers or "unit-switches" which are employed, are secured to a circular base, and are provided with a common magnetic blow-out coil at the centre. This single blow-out coil is a special feature, as it secures the ideal condition of maximum blow-out effect with minimum weight and space; and the number of parts and the amount of wiring necessary are very much reduced. Further the use of a single coil enables it to be made of greater magnetic strength than could be the case if a number of smaller coils were used—one to each switch.

The air-pistons actuating the radial switches work in vertical cylinders; and the air-admission is controlled by needle-valves, operated by iron-clad electro-magnets, which, together with the cylinders, project above the main base-casting of the

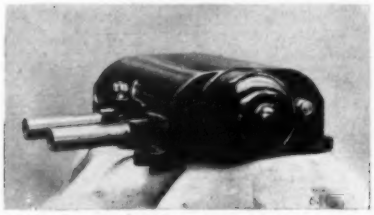


FIG. 4A.—OVERLOAD AND NO-VOLTAGE RETURN RELAY (CASE CLOSED).

turret, as seen in Fig. 1. A single pipe connection supplies compressed air to a central reservoir-chamber, and ports around the latter admit air to the various magnetic valves, and thence to the cylinders; this construction reducing the amount of air-piping and joints to a minimum.

A view of the turret-controller, partly in section, is given in Fig. 3. Here P is the compressed-air supply-pipe, C the air reservoir, p the port leading to the magnetically-operated valve V, and p^1 the port leading from the valve to the cylinder operating the switch S, which is shown in the open position. Another of the switches, S^1, is shown closed, and a section of the cylinder and piston operating it is given. B is the large blow-out coil, and two of the iron pole-pieces emanating therefrom may be seen to the right and left of the figure. These pole-pieces, which are more clearly shown in Fig. 1, are U-shaped, and point alternately up and down; the top ones being bolted to the main iron-casting, and the bottom ones to the extremities of a cast-iron spider. The core of the magnet is fixed to and hangs down from the main casting, and supports the spider and also the attachment for the bottom cover. It may be mentioned that the general arrangement of parts has been somewhat modified since Fig. 3 was drawn, but the latter is near enough for the purposes of a general description.

The contacts of each switch are enclosed in a vulcabeston box or arc shield (Fig. 1), and the magnetic lines from one top and one bottom pole pass through each such box, in a direction normal to that of the line of break of the switch, that is to say, horizontally. The strength of the blow-out field is such that test currents up to 18,000 amps. have been repeatedly and successfully broken, the burning at the switch contacts being negligible.

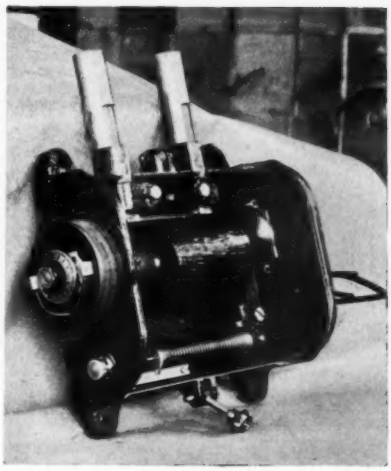


FIG. 4B.—OVERLOAD AND NO-VOLTAGE RETURN RELAY (CASE OPEN).

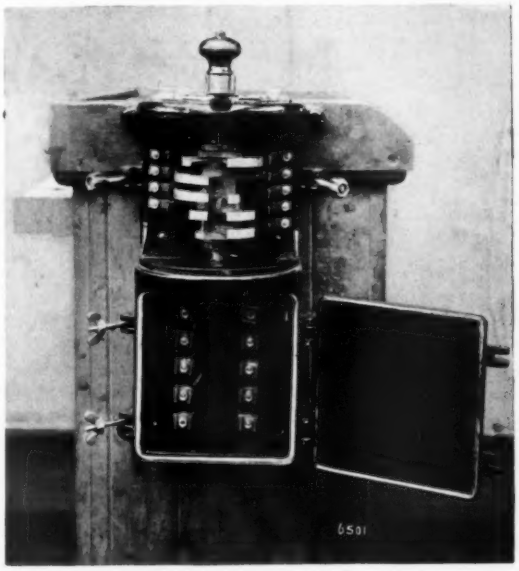


FIG. 5.—VIEW OF MASTER CONTROLLER.

FIG. 6.—HEAD OF MASTER CONTROLLER.

There is, of course, no limit to the length of break or the power of cylinder that may be employed when switches are operated pneumatically. Each switch is closed by the action of the air pressure in its cylinder, a powerful helical spring behind the piston being compressed at the same time. When the switch contacts are brought together and also when they are separated, a spring in the moving arms comes into play and brings about a rolling and sliding motion of the contacts, and so keeps their surfaces in good condition, and prevents all tendency to burn or weld. This spring is shown at *sp*, in Fig. 3. Copper shunts are provided for all working-pins and bushings in the switches; and the contact-plates—which are easily renewable—are of ample area. When the exhaust-port of the cylinder is opened, the spring under the piston drives the latter up and opens the switch. The switch-terminals are shown at *T*, *T*, in Fig. 3, both these and the switch-parts being insulated from the circular base-plate of the controller by sheets and bushings of vulcabeston. It is a good point that the terminals are on the opposite side of the base of the switches, the cables being thereby divided off from the latter. Another good point is that the low-tension circuit-terminals on the magnet-valves are well-separated from the comparatively high-tension switch terminals. The magnets and valves are enclosed by a hinged truncated cone-shaped cover which can be easily removed; and the switches are enclosed by a revolving cover, the halves of which slide or telescope within each other.

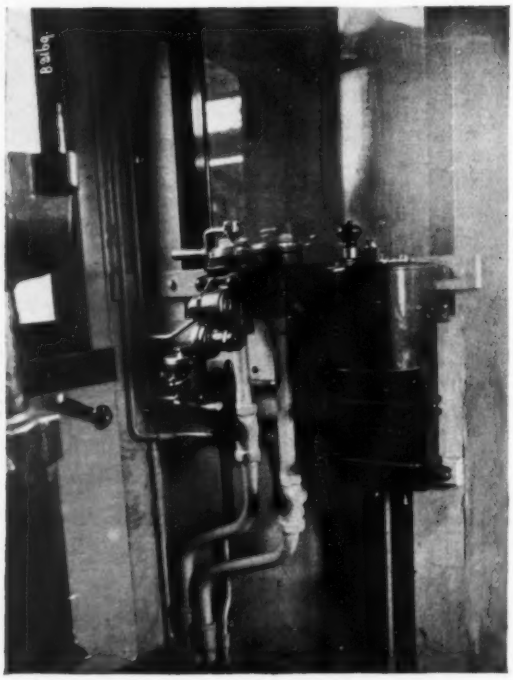


FIG 7.—MASTER CONTROLLER FITTED IN DRIVER'S COMPARTMENT.

In addition to the turret-controller, just described, a complete motor-coach equipment includes a reverser, an automatic excess-current and no-voltage return relay, one or more small master-controllers,

and a switchboard for the controlling of the car lighting, compressor, and battery circuits, this switchboard being depicted in Fig. 8. The reverser, which governs the direction of current through the motors, and consequently the direction of motion of the car, is operated by an air motor, the admission of air being controlled by electro-magnetically operated valves similar to those on the turret controller; and is of substantial and single design. Fig. 4 shows its construction. The overload and no-voltage return relay, which is shown in Figs. 4A and 4B, is connected with the operating magnet of one of the cylinders in the turret, this cylinder actuating the switch which acts as main circuit-breaker. The no-voltage part of this relay, which is mounted on the end of the case, is of considerable importance, its function being to prevent the sudden restoration of full voltage to the motors and consequent flashing thereat, after any unforeseen interruption in the supply of power, due to a break in the third rail, something going wrong with the contact-shoes, a momentary interruption of the supply to the line, etc. When this no-voltage device acts it causes the controller to go back to a point with high resistance in circuit, the latter then gradually and automatically "notching out" the resistance as soon as the supply is resumed. It should be noted that the no-voltage action of the relay is not so instantaneous as to take notice of momentary interruptions due to the car contact-shoe passing over points or crossings; and also that it does not act when the supply is suddenly cut off and then suddenly comes on again. Hence the term *no-voltage return relay.*

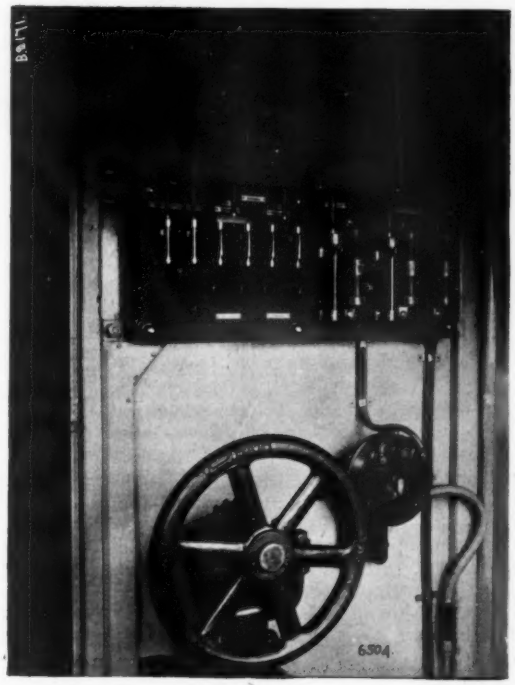


FIG. 8.—SWITCHBOARD FOR CAR LIGHTING, AIR COMPRESSOR, AND BATTERY CIRCUITS.

The connecting-link between the electric and pneumatic gear and the human agent —the driver—now claims our attention. This—the master controller—is wonderfully compact, as will be seen by the following illustrations. Fig. 5 shows it in elevation, temporarily bolted to the side of a bench, and with its top and bottom cases opened; Fig. 6 is a view of the head; Fig. 7 shows it fitted up in the

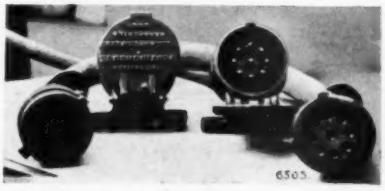


FIG. 9.—LOW-TENSION CIRCUIT CONNECTION.

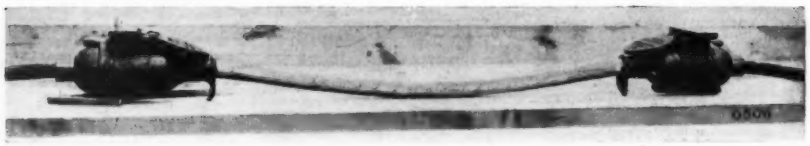
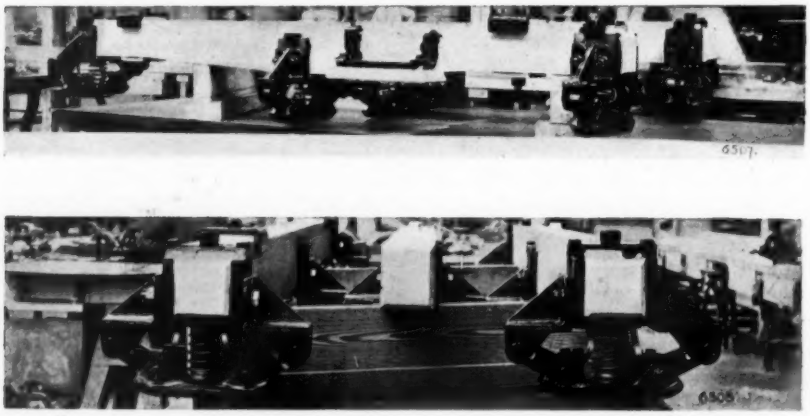


FIG. 10.—LOW-TENSION CONTROL CIRCUIT CONNECTORS.

driver's cabin. The small size and light weight of the master controller, which is so called because it governs the operation of the turret controller, is due to the fact that the currents operating the valve-magnets of the latter are very small, and as they are derived from a low-voltage (seven-cell) storage battery, there is no necessity for arc shields or blow-out coils.

The master controller has five notches for forward running and five for backward running, in addition to the neutral point. At the first "forward" notch the emergency brake-valve is set. At the second, the main supply circuit is closed and the reverse set. At the third—known as the shunting-notch—the motors are connected in series with all resistances in. At the fourth, an automatic acceleration device comes into action and the controller goes on notching-up, provided it is not checked by the limit switch, till the eighth and last series notch is reached, the limit switch coming into play in order to maintain an uniform accelerating current. As the master-controller drum is rotated the pistons in the turret are actuated in due order, and the corresponding switches are closed. When the master-controller handle reaches its last notch the turret switches, which have already been put on, are simultaneously opened, and a number of others simultaneously closed, this making the parallel connections for the motors. Then, subject to the action of the limit switch, the controller automatically notches up to full parallel, and the highest speed point is reached. It is of special importance to note that should the driver throw his handle over to full parallel at the start, the controller will still work automatically and gradually through all the series and parallel positions, so that no harm can come to the motors. A further advantage of this automatic acceleration is that it ensures the utmost economy in power-consumption. Thus, with non-automatic control it has been found that from 10 to 15 per cent. more energy is consumed.

An ingenious safeguard is provided in



FIGS. 11 AND 12.—CURRENT-COLLECTING GEAR.

case the motorman should lose his hold of the controller handle through inadvertence, accident, or sudden illness. The handle, when released, flies back to its neutral position by spring action, and in so doing interrupts a circuit through the magnets shown above the air-pipe seen in Fig. 7. The effect of this is to open a valve and allow the air in the main pipe of the air-brake system to escape, with the result that the brakes are applied immediately throughout the train. When the brakes are not required to act, however, as in reversing, the above-mentioned automatic application may be prevented by passing the controller handle rapidly over the neutral notch. In running backwards, the operation of the controller is similar to its operation with forward running.

The motor coaches that are being equipped for the Metropolitan Railway (London) will be fitted with four 150-h.p. motors, *i.e.*, 600 h.p. in all; and each coach will weigh approximately 39 tons. The full-length train will consist of two motor and four trailer coaches, and it will be possible to split it up into five, four, three, two, or single coach trains as the density of the traffic decreases. The unusual power of these equipments is the reason for the large number of resistance steps in the controller, there being eight series and eight parallel positions. Nevertheless, the weight of the turret resistances, reverser, and pneumatic controlling gear is less than that of an ordinary electro-magnetic control equipment.

The cables are encased in asbestos slate mouldings, so that the fire risk is practically negligible. Fig. 9 depicts the nine-way low-tension controlling-circuit sockets and plugs, which constitute the only electrical connection between neighbouring cars, these being shown fitted together in Fig. 10.

Figs. 11 and 12 give side and end views of the collecting gear for one car. The two outer beams are fixed one at each end of the car, and are provided with a positive collecting shoe at each extremity and a negative shoe in the middle. The shorter middle-beam is placed at the centre of the car length, and carries a negative or return-current shoe only. The necessity for having collecting shoes at each side of the car is explained by the fact that the conductor rail is sometimes on one side of the track and sometimes on the other.

The Poulsen Telegraphone.

By Dr. ALFRED GRADENWITZ.

ONE of the most satisfactory solutions of the problem of recording human speech and sounds of any quality, and reproducing them without any disturbing secondary noises, is afforded by Valdemar Poulsen's telegraphone. By this invention messages, or signals of all kinds, on being transmitted by electrical means to a distance are registered or stored-up at the distant-station by very simple means, based on magnetic action, in order to be reproduced audibly at any time. The principle of the apparatus depends upon the fact that when a magnetisable body, such as a length of steel-wire or ribbon, is acted upon at different points and at different times by an electro-magnet in series with a battery and telephone transmitter, the magnetic impulses set up in the electro-magnet when the telephone is spoken into re-act upon the steel-wire or ribbon and leave upon it a magnetic impression. Conversely, by the action of the magnetised wire or ribbon upon the electro-magnet, the same sounds are reproduced in the telephone as those which originally set up the magnetic action.

The apparatus consisted in its original form of a cylinder *d*, which was surrounded by a helically-wound coil of steel-wire *g*. A stirrup-shaped frame *e* carrying a sleeve *f*, on which was fixed an electro-magnet, was made to rotate round the fixed cylinder. The wire coil, which was stationary with the cylinder, produced a gradual upward movement of the sleeve *f*, carrying the magnet, as this revolved with the frame *e*, and on the sleeve reaching the top the magnet was automatically cut out of circuit and the rotation of the frame stopped, upon which the sleeve and magnet descended to their original position by gravity. (Fig 1A.)

The effect of the passage along the wire of the electro-magnet, to the terminals of which a microphone is connected, is, that there are set up continuous variations in magnetism corresponding with the fluctuations in the current of the microphone circuit, and hence with the acoustic waves striking the microphone membrane. As these variations in magnetism are permanent they may serve to register sounds or language; in fact, when inserting the steel wire into a similar apparatus including an electro-magnet, to the poles of which a telephone is connected, there will on the passage of the wire before the poles of the magnet be produced in the telephone circuit current fluctuations and in the telephone membrane vibrations similar to those by means of which the record had been made.

At the recent Copenhagen Technical and Hygienic Congress, and more recently in London, the inventor presented some novel types of his apparatus, which has now been developed up to the point of commercial utility, and through his courtesy we are enabled to give some particulars as to their construction as well as some illustrations representing them.

The efficiency of the apparatus is a factor of paramount importance. As a rule, the currents reproduced in the telephone circuit are much weaker than those effecting the record of language. Both during the registering and reproducing processes there is a loss of energy: during the registering these losses are due to the demagnetisation of the record; and during reproduction, to the imperfect utilisation of the lines of force present. The demagnetisation of the record should therefore be prevented as far as possible, and in this the speed and the material used play a very important part. The higher the speed at which the steel wire is drawn along in front of the electro-magnet, the greater will be the length of the acoustic

FIG. 1.

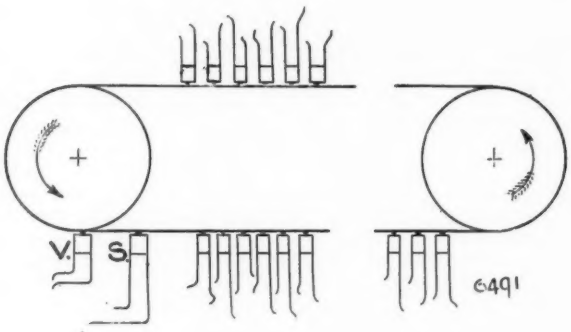


FIG. 2.

waves recorded and the less considerable the demagnetising effect. If the electro-magnet is a one-pole magnet, the efficiency will increase with the speed. The conditions are, however, somewhat different in the case of a two-pole magnet being employed, so as to form the record by a magnetisation transverse to the direction of motion. If indeed, the speed has once become so great that the length of the waves recorded on the wire exceeds the length of the elementary magnets, the transverse demagnetisation will become prominent so as to make any further increase in speed useless.

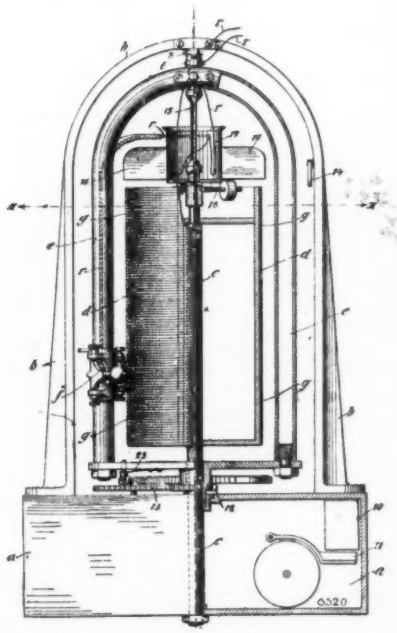


FIG. 1A.

As regards the factors on which the capacity of the instrument depends, the early types of the apparatus were not very advantageous. The limited capacity of steel wires for receiving magnetic records will evidently increase with the magnetic hardness of the material, and in this case it will be possible to use low speeds so as to diminish the length of wire necessary for recording a given number of words and therefore reduce the dimensions of the apparatus. The capacity of the latter could evidently be increased also by using a great number of windings of a wire as thin as possible; this, however, would be attended by the disturbing effect of the resistance of the magnetic circuit being increased at the same time.

In making a reproduction, some losses will be involved by the lines of force of the record being imperfectly utilised. In order to obtain the best possible effects, the pole is placed nearly wholly within the windings (see Fig. 1). The iron cores, as a rule, consist of a piece of soft

annealed iron wire, 1 mm. in diameter, and about 11 mm. in length. A further point of importance in the obtaining of satisfactory records is that the record material should only exhibit a slight permanent magnetisation previous to the experiment. Such slight permanent magnetisations may easily be obtained by erasing any previous magnetisation through the action of a north pole, and thereupon exposing the record material to a slighter action on the part of a south pole. Another method consists in utilising any magnetisation due to previous actions by polarising the electro-magnet during the registering process, *e.g.*, by means of galvanic elements inserted into the recording circuit itself, or connected during records to a special polarisation coil. This polarisation of the electro-magnet will afford the additional advantage of imparting to the molecular magnets of the recording material, during the formation of the record, magnetic shocks resulting in the permeability for small magnetising forces being apparently increased. When augmenting the sensitiveness of the apparatus in this way a respiration may, for instance, easily be recorded and reproduced on the telegraphone.

As the records are exclusively characterised by the variations in the magnetisation produced in the record material, they are, of course, invisible, the mechanical stresses produced by magnetisation in the record material being so small as to become negligible. Any telegraphonic reproduction of the human voice is not accompanied by the disturbing scratching or other secondary noises, as in the case of an ordinary phonograph, the sounds reproduced being soft and continuous as with a very high-grade telephone apparatus.

The records may be reproduced upwards of 10,000 times without any decrease in intensity or deformation being noted; the record, in other words, is everlasting, the magnetism being really permanent. In virtue, however, of another advantage inherent in the magnetic principle the record may be obliterated in a very easy and rapid way by exposing the record material to a comparatively strong magnetisation. This causes the

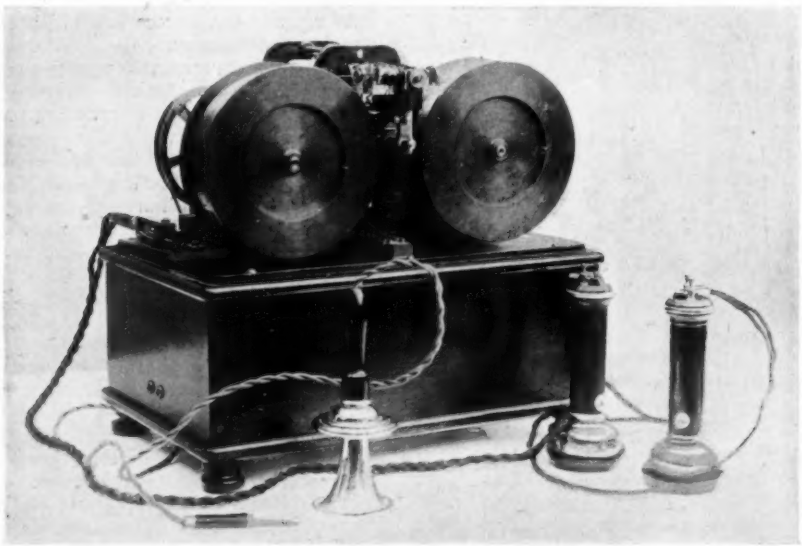


FIG. 3.

magnetic differences of intensity to disappear to such a degree as to prevent any vibrations of the telephone membrane. This obliteration of the record is considered by many as the most remarkable feature of the telegraphone.

The language recorded may, of course, provided the record be sufficiently strong, be transmitted to another recording material, so as to give a weaker copy of the original. During the earlier stages of his invention Mr. Poulsen made some experiments in this direction, without, however, obtaining very satisfactory results. Many suggestions have since been made to the effect of using the telegraphone to strengthen telephonic currents by adding synchronous currents from a sufficient number of copies. This problem, however, has not, so far, been solved in a satisfactory way; though, with better material and higher speeds than those at present used in these experiments, a solution of the question is likely to be found.

When making several records one after another on the same material, without any previous obliteration, all these records will afterwards be heard at the same time, interfering in a regular way. The same material may, however, as suggested by Mr. P. O. Pedersen, the inventor's assistant, be made to receive two different records, capable of being reproduced apart. One of the records is made with a two-pole magnet, the coils of which are connected with one another so that the acting poles are of opposite signs, when, after connecting the coils so as to have poles of the same sign, the record will not be heard. The other record may now be made, and, after again altering the sign of the poles, the former record will be heard and the latter be imperceptible, *i.e.*, the respective records may be reproduced only in the case of the mutual connection of the coils being the same as when making the record.

A special application of the telegraphone, by which the record may be made audible to any desired number of persons, is illustrated by Fig. 2. An endless steel ribbon revolves round two rotating discs in front of an electro-magnet *S*, by which the record is effected. The ribbon next passes before a number of so-called "reading magnets," arranged in a series, and capable of being put in connection with the same number of telephone lines independently of each other. The record finally reaches an obliterating magnet V, and afterwards passes again in front of the recording magnet, and so on.

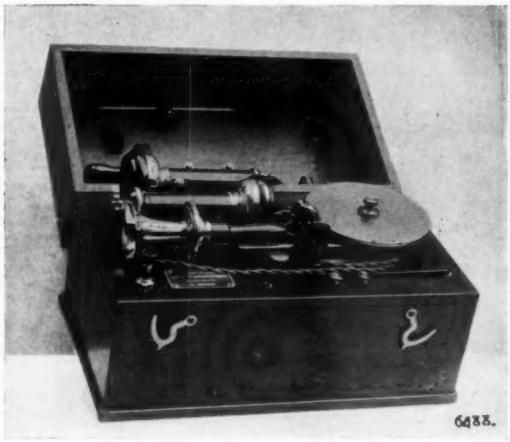


FIG. 4.

The original telegraphone was the above mentioned "drum" apparatus, comprising a steel wire wound on a cylinder in a helicoidal line so as to form at the same time the guiding screw of the electro-magnet. This apparatus, though working very well, affords, as above-stated, but a small speaking capacity in proportion to its volume.

In the so-called "coil" apparatus (Fig. 3) a steel piano wire, about 0·25 mm. in diameter, is employed. This very thin wire passes from one bobbin to another,

before three or more pairs of magnets, at a speed of about 10·64 ft. per second, the bobbins being driven by an electric motor contained in the base of the instrument. The capacity of this apparatus is sufficient to allow of records extending over three-quarters of an hour being made. In the case of only a part of the record being used at a time, its position can be noted by an index, which rotates at a speed equal to that of the reels. In this machine three pairs of magnets and coils are used, the magnets being placed horizontally, one on either side of the wire. The middle pair of magnets serves to effect the record, whereas the pairs on either side are intended for the demagnetisation or erasure of the record. There is, however, only one pair in operation at a time. This arrangement results in the obliteration being effected simultaneously with the record being made, as the wire passes in front of the erasing magnet immediately before passing the recording magnet. The apparatus may be used in both directions. The wire can also be run back to any point, so that the instrument can repeat any part of the record.

In the "ribbon" apparatus steel ribbons are used, of about 0·05 mm. in thickness and about 3 mm. in width. As in the case of the coil apparatus, a large speaking capacity is here obtained in proportion to the volume of the apparatus.

About a year ago, the inventor designed a form of apparatus in which the record material is analogous to that used in mechanical phonographs, a polished reflecting cylinder of magnetically hard material and of similar dimensions to the well-known wax rollers being employed. The speed is about 0·5 m. per sec., and the pitch of the screw formed by the record line about 0·3 m. On account of these reduced proportions, the pole of the electro-magnet must be made very small, being nearly pointed. Strong and beautiful reproductions may nevertheless be obtained with this type of instrument, provided the cylinder be made of good material. Extra-hard, suitably tempered Böhler steel appears to give the best results, although electrolytic iron is also a very good material. In the latest type of apparatus thin steel discs are used instead of steel cylinders, being less expensive and more convenient (see Figs. 4 and 5). The steel plate, which is

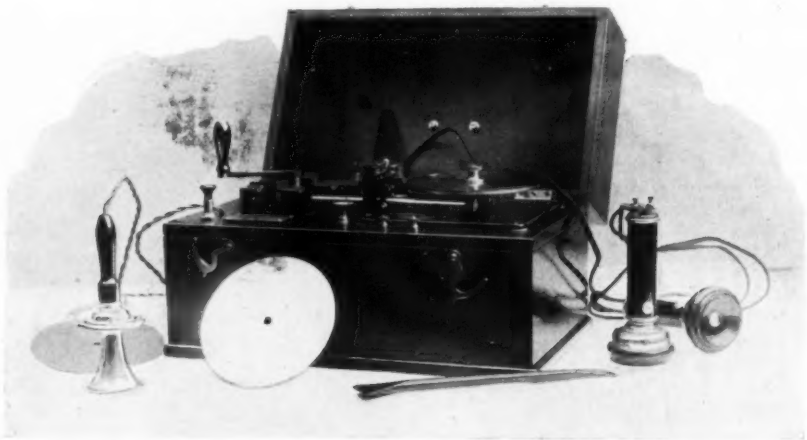


FIG. 5.

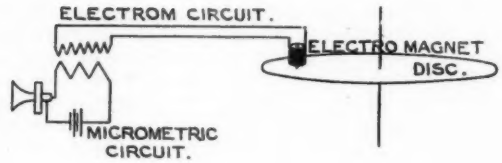


FIG. 6.

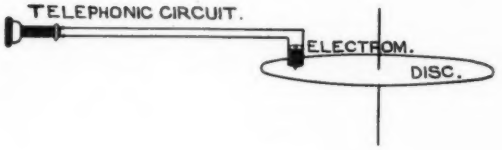


FIG. 7.

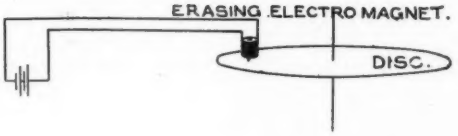


FIG. 8.

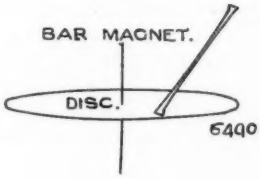


FIG. 9.

capable of receiving records on both sides, may readily be fixed and unfixed, and its dimensions—13 cm. in diameter, 0·5 mm. in thickness—are such as to permit its being forwarded by post to another apparatus of the same kind, where the reproduction may take place. In its operation the new telegraphone is quite analogous to the ordinary gramaphone apparatus, the disc being rotated by a clockwork in a similar way. While, however, the records are not produced with the same degree of loudness as are those of the gramaphone, they are very distinct and their most important feature is the remarkable absence of any scratching or hissing noises. The steel disc is secured to a rotating plate by a milled nut. During the rotation of the disc, the magnet and the coil, being held in a carrier, will gradually be moved towards the centre of the disc by micrometer screws. The speed of rotation is increased as the magnet approaches the centre of the disc, so that the latter rotates beneath the magnet with a constant linear velocity of one-half m. per sec. The obliteration of the record may easily be obtained by passing a bar magnet over the disc (Fig. 9) or else by exposing the disc to the action of an erasing electro-magnet (Fig. 8). A straight magnet is employed in this type of apparatus.

The telegraphone would appear to be specially adapted for use in connection with telephones, for recording business conversations; or for taking a record in the case of the receiving subscriber being absent. The telegraphone, by means of a switch, is connected or disconnected with the telephone instrument, and when in circuit records the complete conversation of both ends of the line over any distance that a telephone can be heard. In America such communications have been recorded on a coil apparatus located in a subscriber's house in New York, the transmitter being in Washington, when the reproduction, in spite of the great distance covered, was exceedingly distinct. As the telephone companies of the various countries are mostly arranged differently, both from a technical and administrative point of view, the same type of telegraphone cannot be employed anywhere as a telephonograph; certain alterations in the arrangement of the circuit and the mechanism of the relays will be necessary in each special case. The disc apparatus, above described, will be found especially suitable by all those wishing to effect their correspondence in a manner as convenient as possible. Disc apparatus with larger plates, allowing of stronger acoustic effects, will be useful in connection with the teaching of language and singing.

In addition to its use as a phonetic apparatus, the telegraphone may be put to a multitude of other applications, capable, as it is, of recording and reproducing any signal expressed by variation in a magnetic field. It therefore seems possible to use telegraphones in connection with wireless telegraphy receivers for recording despatches, especially in the case of magnetic detectors being used.

The cost of running the instrument off an ordinary electric-light supply is stated to work out at one penny for five hours.

BOOK REVIEWS.

Treatise on Thermo-Dynamics.—By Dr. Max Planck, Professor of Theoretical Physics in the University of Berlin. Translated with the author's sanction by Alexander Ogg, M.A., B.Sc., Ph.D., Assistant Master, Royal Naval Engineering College, Devonport. 1903. (London: Longmans, Green & Co.) Price 7*s.* 6*d.* net.

Students of thermo-dynamics ought to be grateful to Dr. Ogg for having made available to them in their own language Professor Planck's masterly discussion of the fundamental principles of this subject and his interesting applications of them to intricate physical and chemical problems. Even to those who are familiar with the text-books on thermo-dynamics by English writers we would recommend a careful reading of this work, as they will find Dr. Planck's treatment different in many respects from that to which they are accustomed and will obtain new light on the subject. In the method followed by the author there are no initial theories or assumptions as to the nature of heat. The bed-rock upon which he starts to build is provided by the two fundamental laws of thermo-dynamics, which are not the outcome of theory but are derived from experience of things as we find them. Starting with these laws, the author develops the subject by a process of clear logical reasoning, and arrives at new and important laws and principles which are of great use in working out practical problems.

The opening chapters, forming Part I. of the book, discuss some of the fundamental facts, and provide some definitions to prepare the reader for what is to follow. Part II. is devoted to a discussion of the First Law and of its applications to homogeneous and to non-homogeneous systems. Numerous applications to processes and reactions in thermo-

chemistry are here discussed, and the author's explanations are all that could be desired. The discussion of the Second Law occupies Part III., and it is here and in Part IV., which discusses the applications of the principles arrived at in Part III. to special states of equilibrium, that the real merit of the author's method and his great skill in analysis become evident. No attempt is made here to introduce the reader to hypothetical reversible processes. From the beginning it is the real irreversible process which is examined, and later on, when the subject has been fully developed, the reversible process is considered as a limiting case of the irreversible.

In the opening chapter of Part III., the author formulates several propositions which can be tested by experiment, and which show the irreversibility of various actual processes, and points out that it is on the facts derived from such propositions that the Second Law is based. If in the future one of these processes should be proved to be reversible, then the entire edifice of the Second Law would fall to the ground, as its universal application would no longer be true. "It is this foundation on the physical fact of irreversibility which forms the strength of the Second Law." In the next chapter, entitled "Proof" (*i.e.* proof of the Second Law), the author begins with the proposition of the impossibility of perpetual motion of the second kind, *i.e.* the impossibility of a change which consists of nothing but the production of work and the absorption of an equivalent amount of heat—and having proved at once from this principle that the expansion of a gas without the performance of work and the absorption of heat is irreversible, he develops the thermodynamic principles for the perfect gases and then shows how these may be transferred to any substance and to any system of bodies. Naturally, in this discussion the function called entropy is prominent, and certainly it would be difficult to find a clearer exposition either of the nature of this function or of its immense importance in the analysis of irreversible thermo-dynamic processes than is here given. Incidentally the author refers to the practice sometimes adopted of considering heat as the product of two factors, temperature and entropy, but he points out at once that the equation for a perfect gas, $Q=\theta d\phi$, which gives rise to this view, is by no means generally true, but holds only in the particular case where the external work performed by the gas is expressed by $p\,d\,V$. When he comes to examine the most general case of a system of bodies, he arrives at the following proposition, which, he says, "is the most general statement of the second law of thermodynamics":—

"Every physical or chemical process in Nature takes place in such a way as to increase the sum of the entropies of all the bodies taking any part in the process. In the limit, *i.e.* for reversible processes, the sum of the entropies remains unchanged."

The Second Law is therefore properly designated "the principle of the increase of entropy," and while it may be presented under other forms, this is the only one of unrestricted applicability to any finite process, and "no other universal measure of the irreversibility of processes exists than the amount of the increase of the entropy to which they lead." This great principle is largely used in the analysis of special problems in Part IV., but it is not possible to give an adequate conception even of the scope of that analysis in the space now at our disposal, and as much of it is mathematical, there is little use in selecting portions for illustration here. We should like, however, to mention the beauty and simplicity of the author's investigation (in Chapter II. of this part) of the state or states of equilibrium which a system of known total mass, but consisting of solid, liquid, and gaseous portions, may assume, and of the conditions of its stability or instability.

This work is from the pen of a great authority on the subject with which it deals, but as students in search of knowledge sometimes find great authorities too deep for them, it may be well to emphasise that no one with a reasonable knowledge of mathematics need be afraid to tackle this volume. In fact, the clearness of exposition is one of its most remarkable features. The original, of course, is in the German language, and this is a translation; but one would not gather that fact from the text itself, and this is a high tribute to the skill of Dr. Ogg.

Practical Shipbuilding: A Treatise on the Structural Design and Building of Modern Steel Vessels. By A. Campbell Holms, M.I.N.A., M.N.E.C.Inst. of Eng. and Shipbuilders, and Surveyor to Lloyd's Register of Shipping. Two vols. 1904. (Published by Longmans, Green & Co.) 48*s.* net.

Literature devoted to the art of shipbuilding has hitherto been chiefly divided into two distinct classes, the first dealing with the purely practical side of the subject, and the second being confined entirely to the theoretical branch. A proper appreciation of the problem can only be arrived at by a judicious intermingling of the two, coupled

with actual experience in the building. It has long been felt that a work dealing in a popular manner with the structure and its attendant strains would greatly facilitate an intelligent understanding of the decidedly complex problem of building a ship. The present work in a very complete manner supplies this want.

In Vol. I. the text is divided into two portions. The first part is prefaced by a *résumé* of the longitudinal and transverse strains, and the distribution of material to most effectually resist them.

In order that vessels may be classed with due regard to their qualities of strength and seaworthiness, the scantlings are determined by means of tables compiled by the registration societies. Upon compliance with these requirements depend the amounts of the insurance premiums. The parent, and oldest, of these societies is Lloyd's, the earliest existing copy of the register-book being one current for the year 1764 ; but at that time it existed solely for the convenience of the underwriters. Other important registration societies are the British Corporation and Bureau Veritas, each of which have their own distinctive methods for determining scantlings, and which have for their objects the attainment of the strongest form of hull consistent with economy in weight.

Chapter V. is devoted to the various types of vessels demanded by the exigencies of modern trade. Following this is a chapter on freeboard, and then the author enters into a most detailed account of the integral portions of the vessel's structure. This is dealt with in a decidedly unique and interesting manner, and one which cannot fail to be appreciated by practical men. As each item is dealt with, the work which it will be called upon to perform is reviewed, and the reason for the disposition of the material is clearly indicated.

Incidental to the comparatively recent innovation of extensive flanging of floors, bulkheads, etc., an interesting experiment carried out by Lloyd's in 1892 is mentioned, in which it was proved that the extra $\frac{1}{20}$-in. in thickness required for floors, which are under compressive stress, is not required in the case of bulkhead plates, which are chiefly subject to lateral stress, and that by increasing the depth of the stiffening flange of a plate about 20 per cent. more than the depth of an ordinary angle flange a much more rigid bulkhead is attained.

The internal fittings, such as pumping, flooding, draining, fire-service, etc., occupy a chapter to themselves ; whilst another is devoted to ventilation, refrigeration, insulation, heating, etc. These, particularly in the present days of large passenger-ships, fruit and frozen-meat steamers, etc., form an important subject in themselves, and, treated in the able manner affected by the author, greatly enhance the value of the volumes.

Part II. is devoted to the work of preparing and erecting the ship — from the drawing office, through the various stages in the yard, including the important (but hitherto almost untouched in book form) feature of supporting and shoring the vessel whilst building, and the launching operations.

The final chapter deals in a popular manner with steel manufacture, mechanical qualities, steel castings, etc.

The text is profusely illustrated in Vol. II. by a very large number of detail drawings, giving scantlings and arrangements for all parts of a wide range of vessels. We can confidently state that this is the most complete manner in which modern practical shipbuilding has yet been presented in book form. Of course, the work claims to deal with practical shipbuilding only as it actually exists in the present day, and thus will necessarily require constant revision in order that it may maintain the position which it undoubtedly may lay claim to—that of being the standard practical text-book.

An important characteristic is the complete and systematic manner in which the text has been indexed, a feature of utmost importance in a volume of 597 pages of letterpress. The author is to be congratulated upon the successful culmination of what is evidently the result of many years' private work, and of a lifetime's practical experience and observation. The volumes will prove of inestimable help to the student ; whilst, to those of riper experience, they present in a condensed form the most up-to-date methods which are the outcome of our experience as the premier ship-building nation.—*H. B. D.*

The Grant and Validity of British Letters Patent for Inventions. By James Roberts, M.A., LL.B., of the Inner Temple, Barrister-at-Law. With many diagrams. 1903. (London : John Murray.) 25*s.* net.

It would be an interesting problem to try to find how many inventors who lodge specifications at the Patent Office really know anything of the law relating to inventions. It goes without saying that every inventor is perfectly convinced of the novelty of his invention ; and, in this state of mind, the chances are that, if he draws up his own specification without outside advice or guidance, he will lay claim to more than he is properly entitled to cover. Yet we scarcely think that inventors as a class will be easily

induced to consult or to study such a work as that now before us, although many would undoubtedly profit much by so doing. But it is for inventors, and not for lawyers, that the book is written, although the author hopes it may be useful also to the latter class. In this hope we do not think he will be disappointed, as there are many points discussed in a manner which will assist a lawyer who is not a specialist in patent law, but may have occasion to refer to that subject, to a clear understanding of the legal principles; while the abstracts of leading cases given in Part II. make the volume very useful as a work of reference. Inventors, however, are on a different footing, and are too often found rushing into print to condemn the law without having made any attempt to understand it. If they could be persuaded to study carefully all that Mr. Roberts has to tell them in these pages, they would save themselves and others a vast amount of trouble, and there would be fewer invalid patents granted at Staple Inn.

When we remember that patent law is by no means simple, and that familiarity with all its details can only come with careful study or long practice, we are able to realise that the task Mr. Roberts has set himself is by no means simple. It is therefore all the more creditable to him that his treatment of the subject should be so satisfactory. He has taken great pains to make his explanations clear, and, wherever possible, has introduced practical illustrations to help this end. Great care has evidently been taken in the preparation of the abstracts of cases, as not only is the list a very long one, but drawings have been freely reproduced so that the reader may more easily understand the facts of each case. There is a good index at the end of the volume. If we take it for granted that inventors are not only willing to learn the principles of patent law, but also able to understand these principles and all their applications, then this volume should be of material assistance to them. There are numerous works on the same subject, no doubt; but the present volume is more original than many of its predecessors, and has much to recommend it. It is beautifully printed in excellent type, and in every way it reflects great credit on the publisher.

Liquid Fuel and its Combustion. By W. H. Booth. (London: Archibald Constable & Co., Ltd.) 24*s.* net.

(First Notice.)

Nearly forty years have passed since means were devised for utilising as fuel the residuum from petroleum refineries. Previous to the year 1875, thousands of tons of the residue left after the distillation of the more volatile constituents from crude oil were annually burnt in open pits around the Baku refineries—a residue, every pound of which was capable of evaporating 15 to 16 lbs. of water. Attention was directed towards this waste of residuals by several persons simultaneously, with the result that it was discovered that astatki, in reality, constituted a most valuable fuel when pulverised or atomised by means of a jet of steam.

Interest in liquid fuel was first aroused in England (in 1878) when Mr. Ayden read a Paper before the Institution of Civil Engineers dealing with the subject, and the discussion which followed served to illustrate what a limited knowledge of combustion many engineers possessed. Since that date innumerable articles and papers have been published, but until recently we were unaware of the existence of any important work devoted to the subject of liquid fuel.

Mr. W. H. Booth's "Liquid Fuel and its Combustion" certainly fills a long-felt want and the well-bound, clearly-written, and profusely-illustrated volume reflects credit upon the publishers as well as upon the author. Much of the information spread over 32 chapters and 10 appendices might, with advantage, perhaps, have been concentrated in a less number of chapters, to which ready reference could have been assured by paragraphing the contents of each.

There is, however, much useful information that is not indicated in the title distributed over the 400 pages; and the work is, without doubt, an important addition to the literature of liquid fuel.

In every branch of engineering, scientific knowledge becomes daily more necessary, but in no branch, perhaps, is the study of science more essential than in that department which treats of the combustion of fuel and generation of steam. Without a rudimentary knowledge of chemistry, all an engineer's energies may be wasted in profitless work, solely on account of failure to realise some all-important scientific fact. For a long time some engineers of the old school were inclined to attribute to liquid fuel evaporative performances in excess of those attainable when calculated from the theoretical thermal value of the petroleum, and to account for such results by peculiar chemical reactions in the furnace, or even to credit the steam used as a pulverising agent with fuel properties. It is obvious that, even if steam is dissociated into its constituents, abstraction of heat from the furnace is unavoidable, which heat is liberated when combustion takes place immediately

afterwards, as nascent hydrogen or oxygen could not exist, as such, in a furnace.

Mr. Booth, we are pleased to note, does not under-estimate the value of information derived from chemical analysis and calorimetric tests, but the importance of such tests is not always admitted, although they are the only means of knowing the total number of heat units available for external work, after satisfying negative-producing impurities. The actual evaporative performance of a boiler can only be ascertained by a practical demonstration, as so many conditions, irrespective of the fuel value, influence this end, but when the exact number of available heat-units is known, no errors can arise from over-estimating the thermal value of the fuel, such as frequently happens without analyses. Oxygen and suspended water depreciate the calorific value of a fuel considerably, and in practice poor evaporative efficiencies are often attributed to defects in the combustion chamber, when impurities in the oil are the cause. In practice, the evaporative results very closely approximate those estimated by calculation from analyses, when due allowance is made for unavoidable losses.

We regret to note the lack of definite information on the subject of air atomisation, upon which more direct interest centres than even Mr. Booth indicates in his work. The relative value of steam and air pulverisation needs settling by an exhaustive series of experiments. Does steam perform any more important duty than mere pulverisation, such as some authorities have asserted, or does it not? Can low air-pressures be brought to practical use by suitable devices, or can they not? If such results can be substantiated as those mentioned on p. 250, where an air-pressure of one or two pounds was used successfully, and less than two per cent. of the generated steam was employed for compressing the air, steam atomisation should receive its death blow. We are inclined to discredit such results, because experiments conducted recently with Russian oil necessitated—with the burner used—2 lbs. of air per lb. of fuel, and a pressure of at least 15 lbs. to properly pulverise the oil. Air is obviously the most correct form of atomising agent; for, whilst steam is a non-supporter of combustion, and a diluent which carries away heat from the furnace, air is a supporter of combustion, and should, when heated, not only effectively atomise the fuel, but cause almost instantaneous and perfect combustion, and reduce (by more than 10 per cent.) the quantity of air required to be admitted to the furnace. One of the chief points urged by Mr. Booth throughout his work is the need for a high furnace temperature to ensure perfect combustion, and we think he has certainly made a good case. The importance of this condition has not always, we venture to think, been fully appreciated by advocates of liquid fuel. Length of flame is largely determined by the intensity of combustion and perfection of air admixture, and everything should be done to induce a high initial temperature, and consequently a shortening of the length of flame, thereby bringing the highest temperature to bear on the front of the furnace, and preventing contact of imperfectly consumed products with cool surfaces of the boiler. Air atomisation promotes such conditions—as may at once be seen by applying air for steam to the burners, the intensity of heat being rendered at once apparent by the increased luminosity and the diminished length of the flame; but Mr. Booth attaches considerable importance to the design of refractory furnaces, and considers that much may yet be done in this way.

Microscopic Analysis of Metals.—By F. Osmond, edited by J. E. Stead, F.R.S., F.I.C. (London: Griffin & Co.) Price *7s. 6d.* net.

This little book embodies the author's well-known papers "Metallography considered as a Method of Assay" and "General Methods for Micrographic Analysis of Carbon Steels." These papers are familiar to many metallurgists in the original; the present publication is, however, acceptable in that all English-speaking students have ready access to Osmond's work. As is well known, the author's generalisations are not accepted by all metallurgists, but all agree as to the high character of the work done, and readily admit it to be worthy of the most careful study. The book will therefore be valuable to all students of the growing science of metallography. The illustrations are exceptionally well produced, but surely that on p. 116 represents a higher magnification than 100 diameters, as stated in the text and below the figure. A footnote on page 110, referring to the "solder" of a Le Chatelier pyrometer, is vague.

In addition to the Papers quoted, two appendices conclude the book: (1) apparatus employed in micro-photography, and (2) the relative softness of austenite.—*P. L.*

BOOKS RECEIVED.

Analyses of British Coals and Coke Collected and Compared, Part III. Reprinted from the *Colliery Guardian.* London: 30 and 31, Furnival Street, Holborn, E.C. Price 6*d.*

Tables of Multiplication, Division and Proportion. For the ready Calculation of Quantities and Costs, Estimates, Invoice Prices, Interests and Discounts. Weights and Strengths, Wages and Wage Premiums. By Robert H. Smith, M.I.Mech.E., etc. Westminster: Archibald Constable & Co., Ltd., 2, Whitehall Gardens. Price 6*s.*

Geological Survey: Bulletin No. 8. Geological Sketch-Map to accompany Report on Lennonville, Mount Magnet, and Boogardie, Murchison Goldfield. By Chas. G. Gibson, B.E. Perth, Australia: Wm. Alfred Watson, Govt. Printer.

The Oil Fields of Russia. By A. Beeby Thompson, A.M.I.Mech.E. London: Crosby, Lockwood & Son, 7, Stationers' Hall Court, Ludgate Hill, E.C. Price £3 3*s.* net.

Heating by Hot Water, Ventilation, and Hot Water Supply (Third Edition). By Walter Jones, M.I.Mech.E., etc. London: Crosby, Lockwood & Son, 7, Stationers' Hall Court, E.C. Price 6*s.* net.

Radium, and all About It. By S. Bottone. London: Whittaker & Co., 2, White Hart Street, E.C. Price 1*s.* net.

Oil Engines. Their Selection, Erection, and Correction. By W. A. Lookey. London: Merritt & Hatcher, Ltd., 2, Grocers' Hall Court, Poultry, E.C. Price 1*s.* net.

Workshop Costs for Engineers and Manufacturers. By Sinclair and Frank Pearn. Manchester: Technical Publishing Co., 287, Deansgate. Price £1 1*s.* net.

Laboratory Exercises with Primary and Storage Cells. By Karl E. Guthe, Ph.D. Michigan: George Wahr, Ann Arbor. Price 45*c.*

Motors and Motor Driving. By Sir Alfred C. Harmsworth, Bart. Third Edition. (London: Longmans, Green & Co., 39, Paternoster Row, E.C.) Price 9*s.* net.

Junior Institution of Engineers: Record of Transactions. Volume XIII. Session 1902–3. (London: Percival Marshall & Co., 26–29, Poppin's Court, Fleet Street, E.C.) Price 10*s.* 6*d.*

Modern Engines and Power Generators. By Rankin Kennedy. Vol. II. (London: The Caxton Publishing Co.)

North of England Institute of Mining and Mechanical Engineers. Subject Matter, Index of Mining, Mechanical and Metallurgical Literature for 1901. Edited by M. Walton Brown. (Published by the Institute, Newcastle-on-Tyne.) Price 42*s.*

Magnetism and its Elementary Measurement. By W. Hibbert, F.I.C., A.M.I.E.E. (London: Longmans, Green, & Co., 39, Paternoster Row, E.C.) Price 2*s.*

The Story of the Atlantic Cable. (London: Geo. Newnes, Ltd., 7 — 12, Southampton Street.) Price 1*s.*

Subject List of Works on Electricity, Magnetism, and Electro-Technics in the Library of the Patent Office. (London: Patent Office, 25, Southampton Buildings.) Price 6*d.*

Electric Lighting for Amateurs; Mechanical Drawing Simply Explained; Nos. 21 and 22 of the Model Engineer Series. (London: Percival Marshall & Co., 26—29, Poppin's Court, E.C.) Price 6*d.* each.

Modern Electric Practice, Vol. III. Edited by Magnus Maclean, M.A., D.Sc. (London: The Gresham Publishing Co., 34, Southampton Street, E.C.) Price 9*s.*

Elementary Mensuration. By G. T. Chivers. (London: Longmans, Green & Co., 39, Paternoster Row, E.C.) Price 5*s.*

The Model Locomotive. By Henry Greenly. (London: Percival Marshall & Co., 26—29, Poppin's Court, E.C.) Price 6*s.*

British Engineering Standards Coded Lists. Issued by authority of the Engineering Standards Committee. Vol. I.: Rolled Sections for Constructional Iron and Steel, Tram Rails. (London: Robert Atkinson, Ltd., Salisbury House, London Wall.) Price 21*s.* net.

The Best Method of Sewage Disposal for Small Communities. By F. Wallis Stoddart. (Bristol: J. Wright & Co.) Price 6*d.*, stiff boards 1*s.*

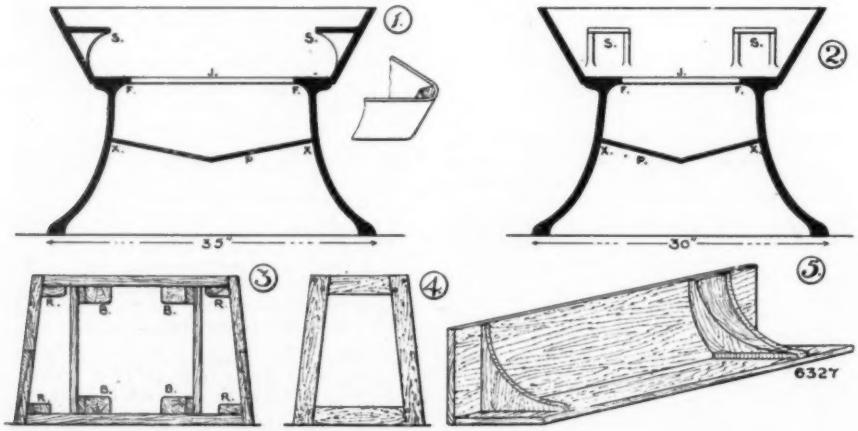
Patents Simply Explained. No. 20 of the Model Engineer Series. (London: Percival Marshall & Co., 26—29, Poppin's Court, E.C.) 6*d.* net.

Workshop Practice Notes.

By W. H. WILSON.

Special and Original Methods of Moulding that present a Principle which may be applied with advantage always appeal to those on the look-out for Up-to-date Practice.

A good example of constructive pattern-making and moulding is shown in the illustrations Figs. 1 to 5, with a description of the methods employed in building the pattern and moulding the same. The subject of the illustration is a machine base with a water-trough and four supporting brackets *S* cast in one piece. The sectional elevations of the casting—Figs. 1 and 2—show that the base is arranged with a centre plate *P*. This is inclined in four directions, and represents the bottom of a lower trough formed for the purpose of collecting the excess lubricant which flows into it after use on the machine. During the passage it is filtered through the perforated metal sheet supported on the flange *F*. At the convergence of the inclines of the plate *P* a tap is inserted for running off the fluid. By reference to the dimensions of the base bottom it will be seen that there is a difference of 5 ins. in length and width, as indicated by the dotted lines. Variations were made in the pattern to suit certain conditions, and the means employed to reduce the cost of pattern-making—by the arrangement of core-boxes to suit the larger or smaller sizes—was consequent upon the number of castings required, viz., one off each. The method, however, is one that will recommend itself for a variety of jobs, and probably suggest at times a way out of the difficulties and expense invariably connected with the building up of entire core-boxes for the formation of large curves, set-offs, or similar projections. These form the connecting line or difference from base to body, and on machine-tool work core-boxes of this kind often become as costly as the pattern. The following description explains the construction and moulding of the pattern, which will form an interesting object-lesson in workshop practice. The body of the base, Fig. 3, was built of 1¼-in. timber, stiffened at the corners by pieces of 3-in. scantling running lengthwise across the width, but set back from the top and bottom edges equal to the thickness of timber used for top and bottom of pattern. These blocks also served to make up the deficiency in strength, caused



FIGS 1 TO 5

by forming the large radii at the corners. To ensure further rigidity, rough frames made of 3-in. by 1½-in. timber as Fig. 4, screwed at the corners and planed on the edges only, were placed some distance apart, the sides being screwed to them. The top and bottom thicknesses were stiffened by battens screwed across them, but clear of the frames. On the underside of the bottom a couple of square blocks, B, B^1, 3 ins. thick, were screwed ; these to give a better foundation for the rapping plates. Similar pieces were also fixed on the underside of the top to better secure the lifting plates, which, like the former, were let in level with the face of the timber. A frame 1½ in. thick, half-lapped at the corners, was made to the greatest outside dimensions and fitted over the body. This frame was then attached to the pattern by screws from the inside, previous to the bottom being put in, thus forming a bracing and foundation on which to build up the large curve of the base. In order to avoid feather edges at the junction of the curve with the straight lines of the sides, pieces were rebated across as shown by section lines on Fig. 3. The space between these and the flange being fitted with good dry timber, glued, and temporarily held with "dogs," the lower and thicker pieces being afterwards screwed from the inside, while the thinner ones were held down with wooden dowel-pins driven in from the outside. On the completion of the curve, the thickness of timber forming the bottom was screwed down to the frames ; additional ribs R at the ends prevented any danger of ramming in. The working of the large radii at the corners then completed this portion of the pattern. (It should be stated that in the building of similar patterns the timber for the sides need not be planed to a thickness, but if convenient, run down with the saw and rebated across to form a sufficient surface for the corner blocks and cross-frames.) The timber for the upper trough was planed to the required thickness, cut to the bevel of the sides and ends, and held together by square corner-blocks These pieces were left, as shown on the right of Fig. 1, for the purpose of strengthening the pattern, the external radii only being formed and the inside completed with a "stopping-off piece." The trough and base were separate, but kept in a relative position to each other by a couple of dowel pins. The interior of the base was entirely cored ; the first or bottom core being made in a box, built of 1½-in. timber, with ends notched in sides and screwed. A bottom was put on the box to carry the pieces which form the flanges F in Fig. 1. The top edges of the sides and ends were cut to the correct slopes, as shown by plates P. A couple of strickles worked on the edges formed the crown of the core, and this when inverted in the mould produced the necessary dip. In order to accommodate the variation of the sizes, the core-box for the bottom part of the base was made as follows :—The sides and ends of 1½-in. timber notched in and screwed, the depth of the box about ½ in. deeper than the lowest point X of the plate, Fig. 1. The bottom of the box was crossed with ¾-in. timber, the inclines forming the underside of plate P being made with a block of shaped timber screwed to the bottom. The object of leaving the box ½ in. deeper was to avoid the inevitable thin edges, which would be obvious in forming the inclined planes on the block. On the inside of the box, and level with the top, pieces of timber ½ in. thick—left loose, but kept in position by a couple of wires from the outside—formed a set-back or shoulder on the main core to receive the additional ones made in an open box as shown at Fig. 5. This box consisted of pieces of timber, screwed together to form an angle-plate, in which were placed brackets corresponding in outline to the required curve on the inside of the casting. The brackets were screwed in from the back and bottom, and, being movable, marks were made indicating the correct lengths of core on the insides of the angle-plate. Two of the cores were made with square ends, the other two being formed with ends of the contour of the curve, by loose blocks fitting against the bracket as shown on the right of Fig. 5. The use of an angle-plate with detachable brackets of the requisite form, provides a ready means of removing the excess metal from the insides of curves or set-offs, and it is obvious that this method may be extended *ad infinitum* to all similar projections both in dry and green sand cores. The method of making and fixing cores of this kind, presents no difficulties in any way, and with the advantage of infinite arrangement and form. In this particular case the sections are butted up to one another, and only require to be dressed-off at the corners and across the intersecting lines. Cores of this type should always be well "ironed" to give them stability, and the vents carried through to the main core against which they are fixed. In moulding the following methods were adopted, the operations when completed giving clean and sound castings, with a minimum amount of time taken for their production. The pattern was first inverted, the trough part being placed on a level bed representing the floor line, a cresset or grid, somewhat conforming in shape to the interior of the trough,

having been previously made in open sand to form a buttress. The trough, after being placed in position, was then carefully rammed, the mound of sand being well supported—in addition to the grid—by short lengths of bar-iron dipped in clay-wash ; by this arrangement the necessary resistance was secured, to support the weight of both cores and metal. A bottom part moulding-box without bars, was then staked over the pattern, the sloping mass of sand on the inside being supported by "gaggers" depending from improvised wooden bars wedged across the box part. The ramming of this portion being completed the top surface like that of the bottom was freely sprinkled with parting sand and the base part of the pattern then set in place. The middle part moulding-box being set over the pattern, the spaces at the sides were fitted, as in the preceding case, with temporary wooden bars to assist along with the "gaggers" in securing the body of sand enclosing the whole of the base as shown. A shallow top-part, forming a level surface and representing the bottom of the base, made up the complement of moulding-boxes. After the mould was completed and the pattern drawn, the cores were lowered to their places. The bottom one rested on line *J*, the second one supported by studs placed on the top side of the first, thus forming the intervening space representing the partition or trough bottom *P*. The metal was supplied through four vertical "gates" communicating with horizontal ones at the bottom of the mould, these being set in their respective places previous to locating the bottom part moulding-box. Across the ends of the top box runners capable of holding a good supply of metal were placed over the "gates," the openings being closed with "stoppers," which were lifted simultaneously as soon as the runners were full and during the pouring operation. This mode of running, with the addition of a couple of good "risers," through which the metal could be fed—gave an absence of "cold shuts" and seams, not always dissociated from light castings of large surface. The method of moulding rendered the withdrawal of the brackets *S*—left loose on the pattern—very easy.

Building Platforms.

Operations on the outsides of buildings are often conducted with a great amount of

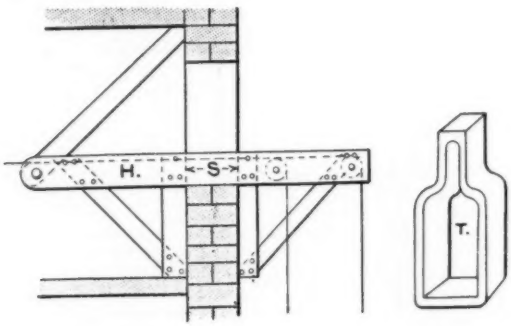


FIG. 1.

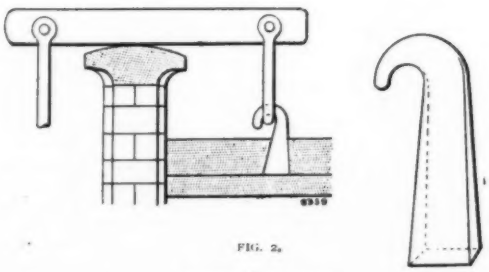


FIG. 2.

BUILDING PLATFORMS.

risk to those engaged on the work, and the scaffolding employed is frequently, from a mechanical point of view, anything but satisfactory. With the uncertain verdicts attendant upon compensation claims, safe devices will be welcomed alike by both employer and workman.

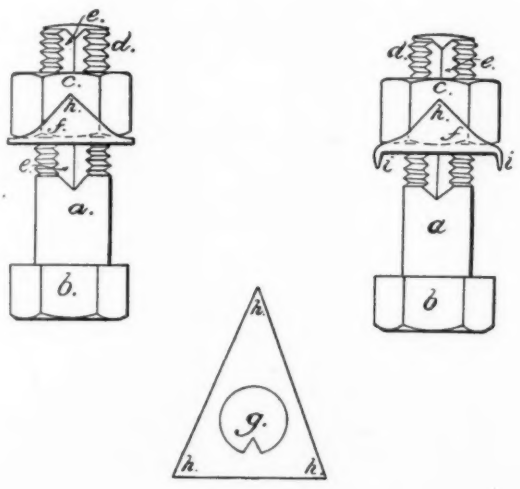
A portable scaffold, which may be extended or modified, is shown in the illustrations. It is the invention of Mr. Ellis of Cincinnati, U.S.A., and consists of a bracing or frame of wrought-iron, riveted together as Fig. 1. The space *S* between the triangles is made to suit the thickness of the outside walls of the building. On the horizontal plate *H* are fixed two small sheaves, over which the pendent ropes pass. These terminate with stirrups *T*, which carry the platform timbers. The free ends of the rope are fixed to a pair of pulley-blocks, the height of the staging being regulated thereby, whilst a lever or clamp provides a further security for retaining the platform at the desired distance. Movable struts on the inside ends of the frames prevent the tilting of the platform, and further ensure the safety of the whole arrangement.

With the almost inevitable adoption of terra-cotta and stock brick in modern building-construction, we think this device will be found a most useful one—not only for constructive purposes, but for cleansing or pointing the outer walls of the finished building. It is without doubt a very considerable improvement over some of the methods in use, as instance on one large modern shop we recently visited. There, on one portion of the building, below the coping, a wrought-iron rail 1½ in. by ½ in. was set up edgeways, supported on horizontal bars set in the brickwork about 1 ft. from the face. This formed a runner on which a grooved pulley fixed in a shackle with swivel supported a pair of rope pulley-blocks. These in turn carried a skep stiffened with iron banding across the bottom and up the sides, and terminating in a ring, to which the hook of the pulley-block was attached. The principal objection to this arrangement was the liability to corrosion of the rails, and the ultimate trouble of renewal.

Another method (Fig. 2) of supporting a skep for outside operations was the setting of large hooked-castings in the concrete which formed the roof of another up-to-date engineering works. The hooks *H* were set at intervals about 2 ft. within the coping. An ash beam with links at each end formed the supporting spar for ropeblocks and skep.

The Barnsdorff Lock-Nut.

An interesting locking-nut has recently been introduced, the details of which are shown in the accompanying drawings. The device consists of a screw-spindle having a triangular channel *e* cut longitudinally on the screw portion of such a depth as is sufficient, in connection with the corresponding projection on the washer *f*, to prevent the latter from turning on the spindle. The opening *g* corresponds in size and shape with the cross-section of the screw portion *d*, and the washer is provided with three projections *h* and two teeth *i*. After the bolt has been screwed down, one or more of the projections *h* are bent up against the side of the nut. In the case of the bolt being screwed into wood the teeth *i* are bent down in such a manner that on screwing down the nut these teeth are forced into the wood as well as the projections *h* being bent up against the nut. This washer should be of value for use in all places where the nuts are not regularly under observation, and where the possibility of their becoming loose would cause serious inconvenience or even danger.

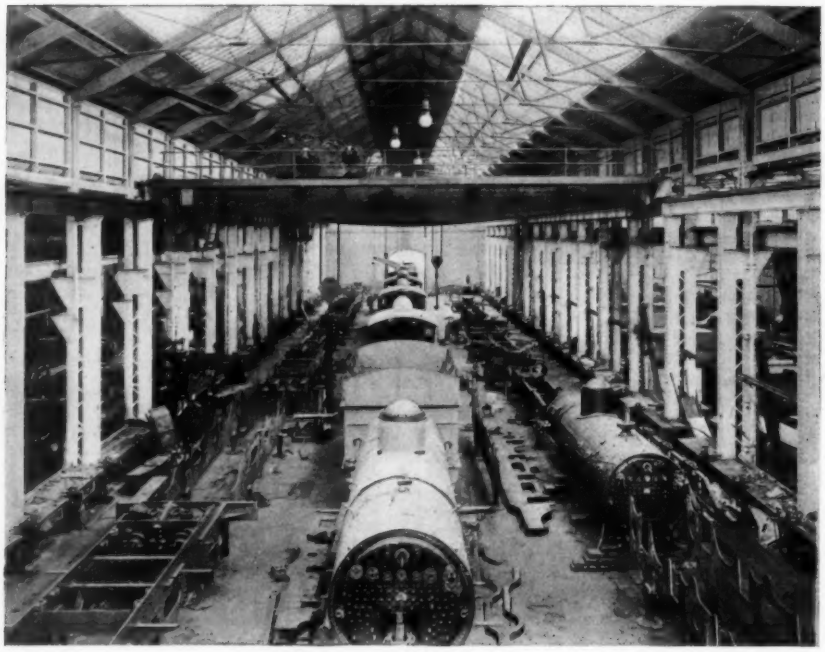


A NEW LOCKING NUT.

Railway Engineering Notes.

New Erecting Shop at the Vulcan Foundry.

ONE of the most interesting firms in the country associated with locomotive history is the Vulcan Foundry, Newton-le-Willows. Founded as long ago as 1832, it still remains in activity in the same place, in contradistinction to other pioneer establishments which have migrated. It may not be generally known that the Stephensons were concerned with the firm almost from its inception, until Robert was appointed engineer-in-chief to the London & Birmingham Railway, and that Mr. Kirtley, the late locomotive superintendent of the Midland Railway, and Mr. Dubs of the North British Locomotive Combine spent part of their time there. The gradual development of the business has rendered extensions to the works necessary from time to time, a new erecting shop recently completed being the latest addition. This shop, a view of the interior of which is reproduced, is conveniently placed beside the tender and machine shops, the former being to the right and the latter to the left in the photograph. The aisles of the new shop are each 300 ft. long by 60 ft. wide and are constructed on the up-to-date system of combined steel and brick-work. The engine erecting department is served by two 35-ton three-motor cranes and the tender shop by one of 12 and two of 25 tons. Pits are provided running the whole length of the building, down the middle of which runs a



INTERIOR OF THE NEW ERECTING SHOP, VULCAN FOUNDRY, NEWTON-LE-WILLOWS.

road laid to many gauges. Outside and conveniently situated is the steaming pit with friction rollers, on which the engines are tried ; they are also run on the straight road after the side-rods are on.

The tender shop is well equipped at one end with plate edging, levelling, punching, drilling, and riveting machinery ; the other end is used for erecting, so that the whole of the tender and tank work is carried out in one shop. The east end has only been built in temporarily in view of further future extensions.

Testing Locomotives.

AN adequate knowledge of the conditions attaching to the economic working of a locomotive is not of less importance than that relating to stationary-engine practice ; and although tests made during actual runs have contributed valuable information to the locomotive engineer, yet it cannot be said that this knowledge is all that could be desired or that it is so thorough as in the case of the stationary engine. The reason is not far to seek. The works or technical establishments of this country, at any rate, have not possessed facilities for the purpose of scientific experiment with the locomotive such as exist for the stationary engine, and it is only within recent years that any attempt has been made to remedy this state of affairs.

In 1890 the Purdue University in America put down a plant for the study of locomotive performance under conditions almost as favourable to the work of testing as those which had been recognised as necessary in tests upon engines of other kinds, an example which might be followed to advantage in this country. Some of the results achieved with this plant were of great importance, either in the way of confirming facts previously surmised or of contributing new information.

Amongst these results achieved it may be mentioned that an American locomotive will develop 1 i.h.p.-hr. with a consumption of 25 lbs. to 26 lbs. of steam per hr. ; that steam delivered from a locomotive is practically dry ; that in a simple engine the maximum cylinder performance results from a cut-off which is between the limit of $\frac{1}{2}$ and $\frac{1}{3}$ stroke ; the determination of the superheating value of steam-pipes within the smoke-box ; the extent to which fuel loss is involved in the discharge of sparks from the funnel ; the action of the steam-jet as a means of producing draught ; the determination of the proportions which should be given to exhaust-pipes and funnel to secure maximum efficiency. The example set by Purdue in the establishment of a locomotive testing-plant has since been followed (1899) at the Columbia University, U.S.A., where also much useful work has been done.

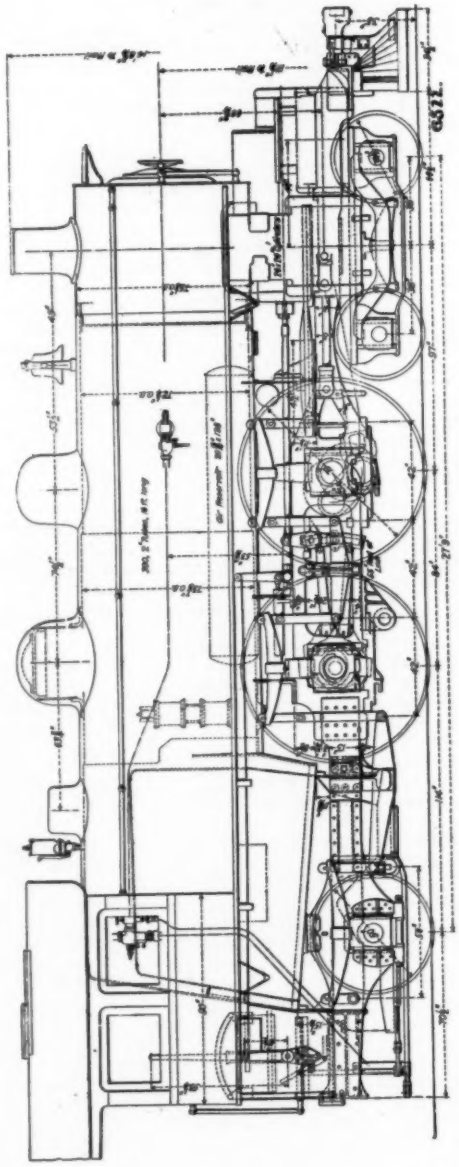
The facilities and plant possessed by British railway companies themselves for testing locomotive performance are not conspicuous by their high value, and consist for the most part of friction rollers not fitted with any brake, the main purpose of which is to show that the engine is in good workable condition.

An exception, however, now exists in the case of the Great Western Railway Co., who have recently put down in their erecting shops at Swindon a fine testing-plant, with which it is hoped that many questions may be definitely settled, particularly that of the relative economy of different classes of engine, either simple or compound. Mr. C. J. Churchward, the chief mechanical engineer to the Great Western Railway, recently described the plant before a meeting of the American Society of Engineers, and from his Paper the leading particulars of the plant are here reproduced.

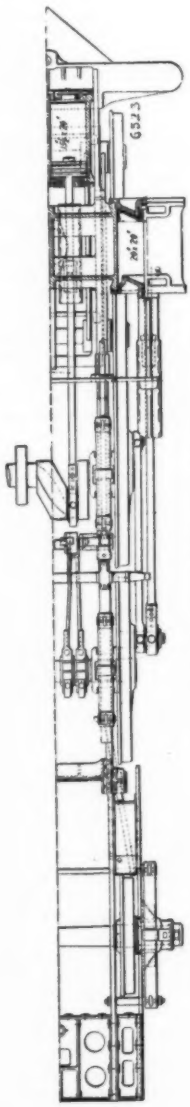
The testing machine consists of a bed made of cast-iron, bolted on to a concrete foundation, with timber baulks interposed for the lessening of vibration. On this bed five pairs of bearings are arranged to slide longitudinally, so that they may be adjusted for any centres of wheels that are to be put upon the plant. In these bearings axles are carried having wheels fitted with steel tyres, on which the locomotive runs. These axles are also fitted with drums, on which band-brakes act for absorbing wholly or in part the power developed by the engine. Outside these band-brakes pulleys having an 18-inch face are provided at each end of the axle for driving link-belts, by which it is intended to transmit the major portion of the power developed by the engine to air-compressors, so that it may not be wasted.

The hydraulic brakes will then only absorb just enough power to enable them to govern the speed of the engine. These brakes are actuated by a water supply from an independent pump, the outlet of this water supply being throttled either by a stop-valve or by a throttle actuated by a centrifugal governor. This latter device enables the speed of the engine to be set at any required number of revolutions and kept constant.

The carrying wheels are 4 ft. $1\frac{1}{2}$ in. diameter. The main bearings are 14 ins. long by 9 ins. diameter. The tyre of the carrying wheels is turned to approximately the same section on the tread as the rails in use on the Great Western line. To make the plant rapidly adjustable to take engines

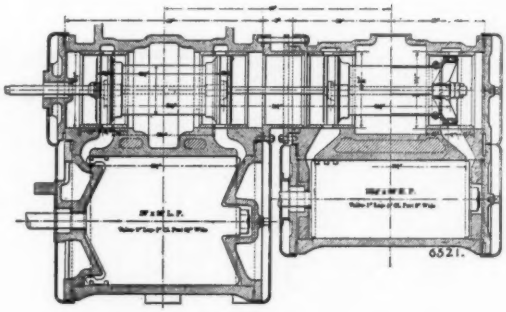


4-4-2 BALANCED COMPOUND LOCOMOTIVE: COLE SYSTEM.



PLAN OF RUNNING GEAR AND CYLINDERS.

having wheels of different centres, the main bed is provided with a rack, and each pair of bearings is provided with a cross shaft having a pinion at either end. These cross shafts are driven from a longitudinal shaft through suitable clutches. This longitudinal shaft is operated by an electric-motor and is capable of being reversed. The engine being run over the machine on an elevated frame which carries it on the flanges of its tyres clear electrically and drops the engine into position on the carrying wheels with their bearings till they are vertically underneath the wheels of the engine to be tested. The frame is then lowered electrically and drops the engine into position on the carrying wheels.



4-4-2 COLE LOCOMOTIVE: DETAILS OF CYLINDERS.

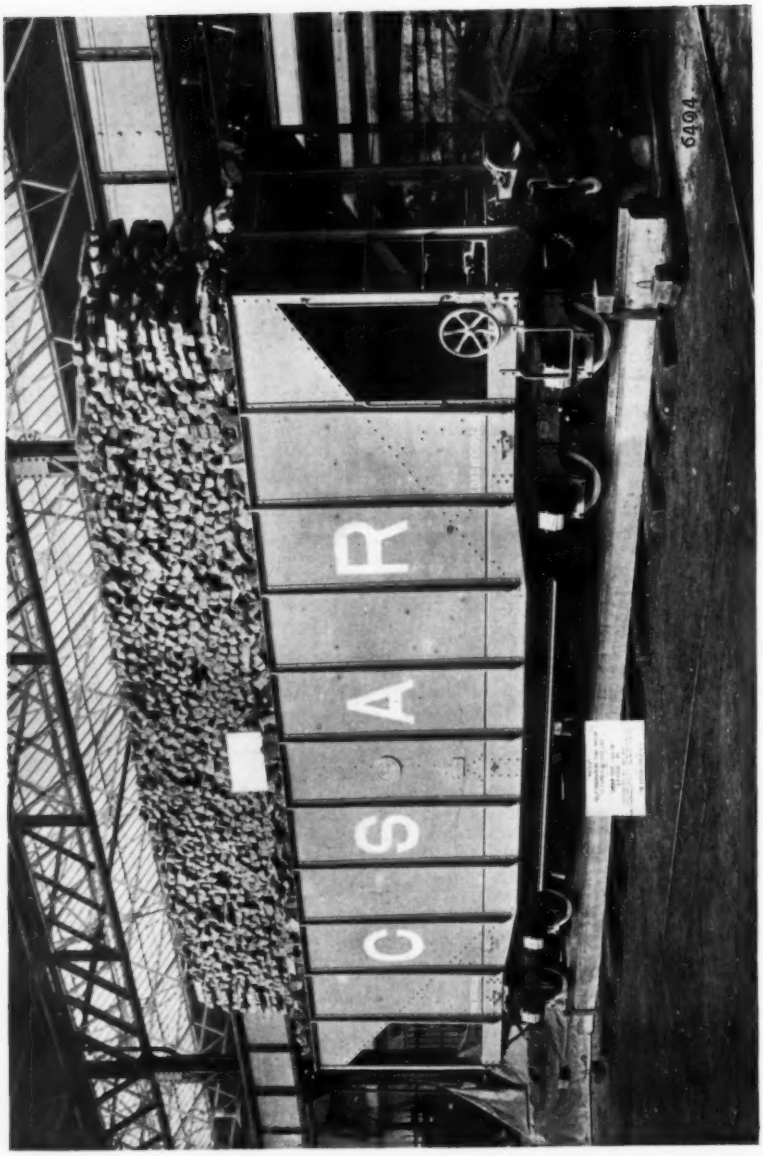
When running engines on trial trips it is essential that the bogie and trailing wheels of engines so fitted should be run as well as the driving wheels, in order that the axle-boxes may take a good bearing and be seen to be in satisfactory condition before handing the engine over for traffic. To accomplish this the carrying wheels are all coupled together by a suitable arrangement of belts and jockey pulleys. It therefore follows that, even when a locomotive having a single pair of driving wheels is run on the plant, all the carrying wheels are rotating and in turn run the bogie and trailing wheels of the locomotive. The jockey pulleys are necessary to retain the proper tension on the belts when the bearings are moved longitudinally.

Owing to the varying height of the foot-plates of different classes of engines, it has been found necessary to provide a firing stage which can be rapidly adjusted vertically. A large coal bunk is provided in connection with this stage and also weighing machines. Two water-tanks are mounted on the same platform, for measuring the water used when running, these tanks being emptied alternately when consumption test is being made.

Under the platform a dynamometer enables the drawbar pull of the engine to be taken, and this, together with counters on the wheels, will enable the actual drawbar horse-power to be measured, and so compared with coal and water consumption for various classes of engines. As engines of different lengths are to be tested, and of necessity have to be fixed at the trailing end to the dynamometer, it is necessary to have a sliding chimney for carrying off the steam and smoke from the engine when running. This has been provided in the form of a long box, having a steel plate running on rollers forming its lower surface, which plate carries a large bell-mouthed chimney. This box not only enables the chimney to slide longitudinally, but will also form a receptacle for ashes and any other matter ejected by the engine, which will be retained and can be examined both for quantity and quality.

Wagons for the Central South African Railway.

By the courtesy of the Leeds Forge Co., Ltd., we are enabled to furnish some particulars, and to illustrate one of the high-capacity wagons recently built by this firm for the Central South African Railway. These wagons are built with pressed steel underframes and bogies, and are provided with longitudinal doors, which are operated by means of a special gear, so as to lock themselves automatically when closed. The door-operating gear is worked by means of a transverse shaft which gears into a longitudinal shaft by means of a worm and wheel, and it is possible to open the doors to any extent desired in order to regulate the rate of discharge. One of these wagons was tested by being loaded with 240,000 lbs. (three times the full working load), and on removal of this load the underframe was found to have no permanent set whatever. The dimensions of the wagon are as under:—Length over buffers, 39 ft. 3 ins.; length inside body, 36 ft. 5½ ins.; width inside body, 7 ft. 5⅝ ins.; height over all from rail level, 9 ft. 9 ins.; centres of bogies, 25 ft. 6 ins.; tare weight, 36,500 lbs.; capacity, 1,428 cubic feet.



HIGH CAPACITY WAGON CONSTRUCTED FOR THE CENTRAL SOUTH AFRICAN RAILWAY BY THE LEEDS FORGE CO., LTD.

Cole's 4-Cylinder Balanced Compound Locomotive.

THE example of the Great Western Railway in ordering a De Glehn compound locomotive for the purpose of experimental study, has been followed by the Pennsylvania Railroad, U.S.A., who have recently put into service a heavy passenger engine built from the drawings of one of the heaviest of the De Glehn type, viz., those at work on the Paris-Orleans line. There can be no finer tribute to the excellence of these engines than for both a British and American company to adopt one as a standard of comparison, although we cannot go to the length of some in pronouncing it "the most successful type of locomotive in the world." That can only be determined after a series of exhaustive and comparative trials, both on the road and a properly equipped testing-bed.

Nevertheless the De Glehn type has been so successful as to cause locomotive designers in France to abandon their own particular designs in its favour, and in America some of the most successful ideas embodied in the De Glehn engine have been adopted in the new engine designed by Mr. J. J. Cole, of the Schenectady Works of the American Locomotive Co., built by them, and recently put into service on the New York Central Railway.

Like the De Glehn engine, the high- and low-pressure cylinders drive two separate axles, but instead of the high-pressure cylinders being on the outside, set back from the smoke box, they are inside forward of the smoke box and drive the first axle. The low-pressure cylinders are fixed outside (in the usual position) and drive the rear axle. The valves, which are both of the piston type, are mounted on the same spindle and are driven by a single valve gear of the Stephenson type. The general arrangement may be gathered from the accompanying drawings.

Other special features of the design, consist in shape of the crank-axle, which has only one cheek to each crank, the middle of the shaft being inclined so as to connect the inner ends of the crank pin. The reciprocating parts are balanced, thus permitting an increased distribution of weight on the driving wheels, which carry, in this case, 55,000 lbs. each. The leading dimensions are as under :--

RUNNING GEAR:	
Driving wheels (4), diameter	6 ft. 7 ins.
Truck wheels (4), ,,	3 ,, 0 ,,
Trailing wheels (2), ,,	4 ,, 2 ,,
WHEELBASE:	
Driving	7 ft. 0 ins.
Truck	6 ,, 4 ,,
Engine, total	27 ,, 9 ,,
Tender	16 ,, 9½ ,,
Engine and tender	53 ,, 8 ,,
WEIGHT IN WORKING ORDER:	
On driving wheels	110,000 lbs.
On truck and trailing wheels	90,000 ,,
Engine, total	200,000 ,,
Tender, empty	51,600 ,,
Tender, loaded	121,600 ,,
CYLINDERS:	
H. p. (2), 17½ ins. c. to c.	15½ × 26 ins.
L. p. (2), 7 ft. c. to c.	26 × 26 ,,
Connecting rod, length, c. to c.	7 ft. 9 ,,
VALVE GEAR: Type	Stephenson link
Valves, piston, diameter	14 ins.
,, maximum travel	6 ,,
,, inside lap: h. p., ¼-in.; l. p.	⅝ ,,
,, outside lap	1 ,,
lead (forward gear, at 11 ins. cut-off)	¼ ,,
BOILER: Type	Straight top
Barrel, diam. inside smallest ring	6 ft. 0½ in.
Barrel plates	13-16 ,,
Smokebox tube plate	½ ,,
Height, rail to centre line	9 ft. 3 1-16 ,,
Smokebox, length	5 ,, 0 ,,
Working steam pressure	220 lbs.
FIREBOX: Type	Radial stay
Length, inside	8 ft. 0⅛ ins.
Width, inside	6 ,, 3½ ,,
Depth at front	6 ,, 8¼ ,,
Depth at back	5 ,, 9 ,,
Crown, side and back plates	⅜ ,,
Tube plate	½ ,,
Firebrick arch	On water tubes
TUBES:	
Number	390
Diameter, outside	2 ins.
Length over tube plates	16 ft. 0 ,,
HEATING SURFACE AND GRATE AREA:	
Heating surface tubes (interior area)	3,248 sq. ft.
,, ,, firebox	175 ,, ,,
,, ,, firebrick arch water tubes	23 ,, ,,
,, ,, total	3,446 ,, ,,
Grate area	50·3 ,, ,,
MISCELLANEOUS:	
Capacity of tender tank	6,000 galls.
Capacity of coal space	10 tons

The engine is to be sent to the St. Louis Exhibition to be tested there with several others, including the before-mentioned Pennsylvania Railroad French-built De Glehn.

Great Central Accelerations.

COMMENCING with July, many important accelerations on the Great Central Railway have been made in the train service affecting all parts of the country. Between London (Marylebone) and Leicester is now being made the quickest run ever achieved, covering the 103 miles in 105 minutes, or at the rate of 58·8 miles an hour. To Nottingham the journey of 126 miles is accomplished in 131 minutes. The Great Central is the first company to make a run between London and Sheffield without a stop, which is performed in the record time of 2 hours 57 minutes. Between London and Manchester the journey is being completed in

3 hours 50 minutes, Huddersfield in 3 hours 45 minutes, Halifax in 4 hours 13 minutes, Bradford in 4 hours 30 minutes, York in 4 hours 10 minutes. The service between London (Marylebone) and Stratford-on-Avon has been accelerated, and offers the quickest and most convenient route. The through service between Newcastle, York, Bradford, Huddersfield, Sheffield, and Southampton, Bournemouth, etc., has been considerably improved, and commencing July 9th through express trains are being run between Southampton and Scarborough by the direct route *viâ* Oxford and Banbury. In connection with the Great Western Railway, the Great Central give an entirely new through service between Leeds, Halifax, Huddersfield, Sheffield, Nottingham, Leicester, and the West of England *viâ* Banbury and Bristol. Nottingham is now brought within 7½ hours of Plymouth and 10 hours of Penzance.

CATALOGUES RECEIVED.

Bever, Dorling & Co., Ltd., Bowling Iron Works, Bradford :—Illustrated catalogue of mill engines, winding and hauling machinery for collieries, steam and electric pumps, etc. A set of useful tables regarding horse-powers, etc., complete the book, which should be in the hands of every up-to-date engineer.

The Temperley Transporter Co., 72, Bishopsgate Street, Within, London, E.C. :—We have received from this firm one of the most attractive catalogues we have seen. It is printed on fine art paper and profusely illustrated with typical examples of the many specialities of this firm for the rapid and economical handling of materials of all kinds, and in going through the book one can very quickly obtain a general idea of the special appliances and their various adaptations, including transporters for wharves, railway sheds, warehouses, goods yards, etc.

Barr, Thomson & Co., Ltd., Netherton Iron Works, Kilmarnock :—Illustrated sheets and price lists of embossed manhole and sludge-hole doors, stamped steel gutters and channels, seamless and weldless unbreakable steel ladles, etc.

Matthews & Yates, Ltd., Cyclone Works, Swinton, Manchester :—Catalogue dealing with the ventilating and electrical specialities with special reference to the cyclone blower and motor as supplied to H.M. Office of Works, for the purpose of ventilating the Debating Chamber of the House of Commons, with a few notes on the ventilation of the House itself.

C. W. Webster, A.I.E.E., Bradford :—Up-to-date motor driving dealt with, with illustrated description of the various parts of the motors. All interested in motor-driving should write for a copy.

The Standard Tool Co., Ltd., Sowerby Bridge :—A well illustrated, up-to-date catalogue of machine tools of all descriptions, of which milling cutters, gear cutters and reamers are made a speciality of by this firm.

National Gas Engine Co., Ltd., Wellington Works, Ashton-under-Lyne :—A well printed catalogue giving a general idea of the type and construction of the engines of this firm, together with the class of workmanship, and the purposes for which they are adapted.

G. & J. Weir, Ltd., Cathcart, Glasgow :—New sectional catalogue, No. IV., showing latest designs in feed and service pumps for power plants.

Thos. Glover & Co., Ltd., 49, Queen Victoria Street, E.C. :—Well-got-up illustrated pamphlet dealing with the "Gothic" gas and oil engines, these are of a very simple type, impulse every revolution, and are without the complicated levers, trip gears, springs, etc., usually seen round the cylinder end of all other makes.

General Electric Co., Ltd., Queen Victoria Street, E.C. :—15th Edition of L Section, catalogue of electric bells and telegraphic supplies. As usual, it is very complete and must be invaluable to all electrical engineers.

NEW MACHINERY AND APPLIANCES.

The Concentric Condenser.

A NEW form of surface condenser has been recently introduced which should prove specially valuable in cases where weight and space occupied are matters of consequence. It will be seen from the accompanying illustration that the design is a very simple one, and that the chief feature consists in the arrangement of the tubes, viz. in an element made up of a series of concentric rings.

It is in this way that the economy in space is effected, a condenser constructed according to this design occupying only one-sixth the space of a standard condenser of the same capacity. The light weight is a consequence of the small number of parts, there being only 30 tubes, no ferrules, and 55 parts altogether in a condenser for a 110-i.h.p. engine as against 400 tubes, 800 ferrules, and 1,325 parts in an Admiralty-type standard condenser of the same capacity.

In the case of a large condenser this would be made up of a number of elements, any one of which can be isolated or removed by closing the cocks provided for the purpose, an advantage in the case of a leak occurring, as a spare element can be readily inserted without the stoppage of either the engine or pumps.

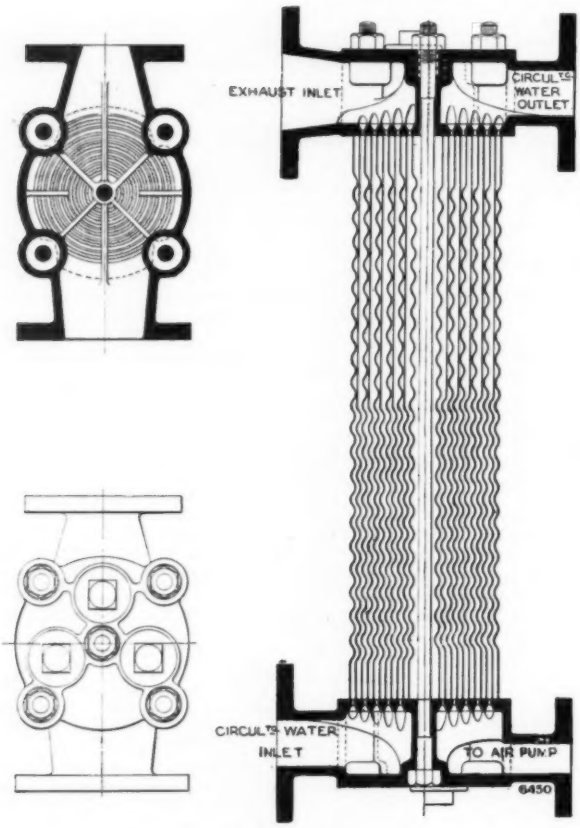
For ordinary work the tubes are jointed with a special composition, which the makers claim has given first-rate results. Where the condenser is used in connection with vapours, or liquids having a corroding effect upon the composition, lead wire is substituted. Any expansion or contraction in

TRIALS OF PATENT CONDENSER.

(Steam Direct from Boiler, Rotary Air Pump, Condenser Vertical.)

Tubes, 11½ ins. long; Cooling Surface, 7 sq. ft.; Tubes, Corrugated

Trial.	Duration of Trial.	Lbs. of Water Condensed.	Gallons of Circ. Water.	Temp. of Hotwell, F.°	Temp. of Circ. Inlet, F.°	Temp. of Circ. Discharge, F.°	Circ. Water Raised, F.°	Degs. difference between Circ. Discharge and Hotwell.	Vacuum.	Boiler Pressure, Lbs.	Circ. Water / Cond. Steam.	I.H.P. at 20 lbs.	Total Units Abstracted.	Units of Heat per lb. of Circ. Water.	Percentage of Heat Extracted.
A	1 Hour	320	800	145½	45	87	42	58½	18	36	25 / 1	16	336,000	42	88·0
B	1 ,,	554	1,000	203	45	100	55	103	14	53	18 / 1	27·7	550,000	55	74·5
C	1 ,,	250	700	114	45	83	38	31	19·5	58	28 / 1	12·5	266,000	38	90·5
D	1 ,,	262	520	129	45	98	53	31	17·5	58	20 / 1	13·1	276,000	53	88·0
E	1 ,,	228	280	161	45	122	77	39	15	52	12 / 1	11·4	215,500	77	85·5
F	1 ,,	219	300	151	45	120	75	31	14·75	40	14 / 1	10·9	225,000	75	87·0



THE CONCENTRIC SURFACE CONDENSER.

the tubes themselves is taken up by springs fixed underneath the bolt nuts, and a clearance of $\frac{1}{16}$ in. is left between the tubes. On p. 139 is a table showing the results of some recent trials made with the apparatus.

Concentric Condensers, Ltd., are the owners of all patents on this device and manufacture, and supply same from 10 horse-power up to any number of horse-power which may be required: at the office of the company, 23, Northumberland Avenue, Charing Cross, W.C., a working model may be seen and all details and prices obtained. The apparatus is undoubtedly of great interest to steam users, whether on land or water, also to users of condensible vapours and gases.

A New Process for Cold-Soldering Band-Saws.

We recently had an opportunity of witnessing an interesting demonstration of a process which promises to meet a want long felt in pattern-making shops, saw-mills, box-making factories, and, in fact, by all users of band-saw machinery. It consists in a simple and effective method of repairing band-saws. This operation is at present effected by brazing, the carrying out of which means that skilled workmen are required and a considerable loss of time is entailed. There are other disadvantages attaching to the brazing process — viz. that the temper of the saw is destroyed by the high temperature necessary, and that after a few repairs the saw becomes useless, owing to the shortening which takes place because of the break taking place just above or below the brazed part.

By the new process, to which the name "Forkor" has been applied, the joint is made by a method of cold-soldering which is very simple, and requires no apparatus beyond a clamp, spirit lamp, and a pair of broad-faced pliers. The broken ends of the saw are, first of all, filed for a length of from three to four teeth, and then brushed over with a white fluid, the composition of which is at present a secret. The ends, thus coated with the liquid, are warmed by the spirit lamp and rubbed with a stick of solder until the surface is well covered with metal; after which a second layer of the liquid is applied. The ends are then clamped in position and heated again until the solder melts, and are then pressed firmly together with the pliers to squeeze out the excess of solder. After dressing with a file the saw is ready for use.

The advantages of the process are that the

temper of the saw is not affected, and should a break occur again it always takes place at the joint. As, therefore, no shortening takes place, the saw can be used for a much longer period than would be possible were the brazing process used. The time occupied is less than half that necessary for brazing, and, moreover, the saw can be used at once. The cost of making a joint, it is claimed, does not exceed 2*d*.

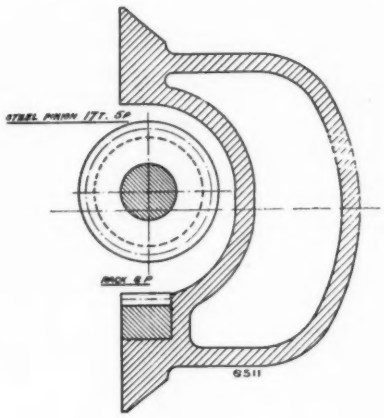
The demonstration we witnessed satisfactorily bore out the claims made on behalf of the method, and it was only when two 9-in. lengths of saw which had been cold-soldered were bent back until they were in contact along their whole length that the joint gave way. The process is being exploited by Messrs. Marshall & Co., 9, Southampton St., High Holborn, W.C., from whom the necessary materials and full particulars may be obtained.

New Radial Drilling and Tapping Machine.

The accompanying illustrations refer to a new machine, which has been designed with the object of getting drilled work off in a minimum time. Sixteen drilling speeds, ranging from 320 to 18 revolutions per minute, have been provided for, each of which is arranged for use with a twist-drill of a certain size. The following table shows the range of spindle speeds and the corresponding drills suitable for cast-iron and steel:—

Diameter in Cast-Iron.	Spindle-Speed.	Diameter in Steel.
$\frac{3}{32}$	320	$\frac{5}{16}$
$\frac{1}{8}$	262	$\frac{3}{8}$
$\frac{5}{32}$	218	$\frac{7}{16}$
$\frac{3}{16}$	178	$\frac{1}{2}$
$\frac{7}{32}$	149	$\frac{9}{16}$
1	122	$\frac{5}{8}$
$1\frac{1}{8}$	101	$\frac{3}{4}$
$1\frac{1}{4}$	83	1
$1\frac{1}{2}$	70	$1\frac{1}{8}$
$1\frac{3}{4}$	57	$1\frac{1}{4}$
2	48	$1\frac{3}{8}$
$2\frac{1}{4}$	39	$1\frac{3}{4}$
$2\frac{1}{2}$	33	2
$2\frac{3}{4}$	27	$2\frac{1}{4}$
3	22	$2\frac{1}{2}$
$3\frac{1}{4}$	18	$2\frac{3}{4}$

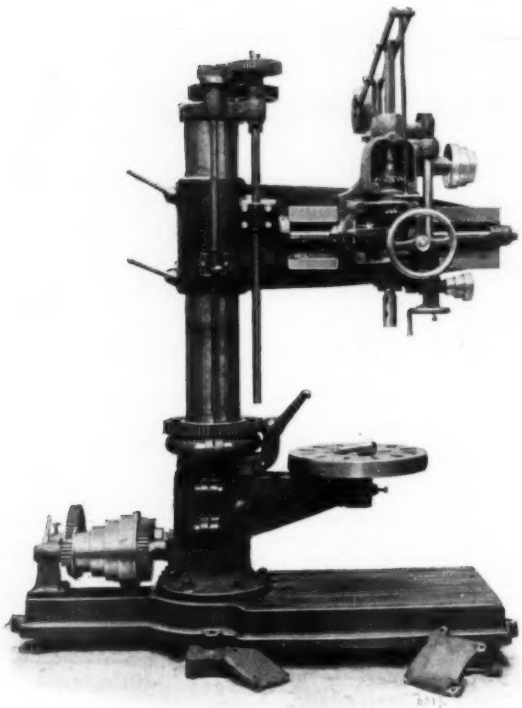
There are six feeds, ranging from $\frac{1}{48}$ in. to $\frac{1}{25}$ in. per revolution of spindle. The driving-cone, which is arranged for a $2\frac{1}{2}$-in. belt, has



RADIAL DRILLING MACHINE: SECTION OF ARM.

four steps of 12 ins., $10\frac{1}{4}$ ins., $8\frac{1}{2}$ ins., and $6\frac{3}{4}$ ins. in diameter respectively. Both driving and overhead cones are turned up on the inside, to ensure a correct balance. The pillar swivels on a ball-bearing, on a stationary column, to which it is clamped by a **V**-shaped ring, which makes practically a solid connection. The arm, as may be seen from the drawing, is of box-section, to resist the combined bending and twisting stresses to which it is subject. It is elevated by a power-driven steel screw, which revolves on a ball-bearing. The saddle is a strong box-casting, and is so arranged that all the gears are guarded. The spindle is 2 ins. diameter, and is driven by a reversible clutch, which, when the spindle is stopped, causes also the feed-motion to cease working. This arrangement is not found on some machines, and broken drills are very often the consequence. Another feature of the machine consists in the connection between the feed-rack and the spindle, whereby self-adjustment is secured for wear, so that no drop takes place when the drill is getting through. The feed-rack pinion is of steel, and is all in one piece with its shaft.

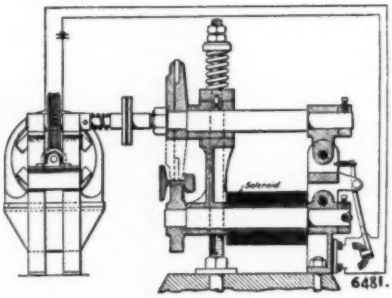
The feed-worms have ball-thrusts to reduce friction. The spindle is adjusted horizontally by a large hand-wheel and rack and pinion, the swivelling motion round the column being operated by a worm and worm-wheel—a convenient way of setting the drill accurately to position. The table is mounted on the lower end of the column, and is very useful for light drilling. When heavy deep work has to be drilled, the table can be swung round to the rear of the machine. The counter-



NEW RADIAL DRILLING AND TAPPING MACHINE.

shaft is driven at three speeds —viz. 360, 295, and 100 revolutions per minute, the two former speeds being intended for drilling and the latter for tapping. With each machine a table is supplied giving the step of the cone, etc., to give the correct speed for the various diameters of drills. The correct tapping-speed is one-third of the drilling-speed, so that if the hole has to be tapped the belt on the driving-cone remains where it is and the counter-shaft is run at one-third the speed—*i.e.* 100 revolutions per minute. The nitre wheels at the base of the column and in the arm, together with all pinions, are of forged steel, and all gears are machine-cut from the solid. The weight of the machine is 38 cwts.

It is manufactured by Messrs. D. Mitchell & Co., Ltd., Keighley, who make a speciality of radial drilling machines up to 7-ft. radius.



THE DETECTION OF THE FINISHING TEMPERATURE OF STEEL RAILS BY THE THERMO-MAGNETIC SELECTOR.

(To illustrate Abstract on page 64—July Number.)

ENGINEERING ABSTRACTS.

The Mechanism of Combustion. **Prof. Harold B. Dixon, M.A., F.R.S.**—This Paper is of the highest order of importance to all who are occupied with gas-engine research, embodying, as it does, the latest results of investigations made as to the nature and character of flame, and the propagation of explosion waves. The author opens by examining the causes of luminosity in hydrocarbon flames, which we may pass by, and proceeds to consider the pressures produced in explosions. Just as Bunsen was a pioneer in testing the Law of Mass in gases, so also he led the way in investigating the pressure and temperature produced by the explosion of gases in closed vessels. His results led him to the erroneous conclusion that there was a discontinuous combustion in explosions. When electrolytic gas, or when carbonic oxide with half its volume of oxygen, is fired, only one-third of the mixture is burnt, according to Bunsen, raising the temperature of the whole to about 3000° C. No further chemical action then occurs until the gaseous mixture falls, by cooling, below 2500° C. Then a further combustion begins, and so on *per saltum*. Bunsen also in the same paper makes the important statement that the rapidity with which a flame spreads is synchronous with the attainment of the maximum temperature and with complete combustion. The author does not know on what grounds Bunsen based this statement, which he has found to be nearly true of the detonation-wave itself (*l'onde explosive* of Berthelot), but wholly untrue for the initial periods of the explosion. Other observers have on the whole confirmed the work of Bunsen as to the "effective pressures" produced in the explosion of gases. But, working with delicate indicators, Mallard and Le Chatelier found that, with all rapidly exploding mixtures, very high pressures were often produced during very small intervals of time. These fugitive pressures are due, according to Mallard and Le Chatelier, to the compression-wave which is propagated as the inflammation spreads from layer to layer, and may become of enormous intensity in the detonation-wave itself. As their object was to measure the mean pressure in the whole mass of gas, they abandoned the delicate indicator and used a Bourdon gauge. From the curves of pressures so registered they obtained expressions for the rate of cooling of the products of combustion, and so calculated the maximum pressures and temperatures of the explosions. Their results may be summarised in the statement that the maximum temperature of explosion of moist electrolytic gas is 3350° C. and the mean specific heat of steam between this temperature and 0° is 16·6, dissociation being very slight, if any, between these limits; on the other hand, the mean specific heat of carbonic acid rises to 13·6 at 2000° C., and above this temperature dissociation begins. The diatomic gases (O_2, N_2, CO, etc.) also show a rise of specific heat, though far less marked than steam or carbonic acid exhibits. In 1885 Berthelot and Vieille published their researches on the pressures produced in the explosion of gases. They measured the pressures by determining the maximum acceleration of a piston of known weight moved against gravity, making a correction for the cooling effect of the walls when a small explosion vessel was employed. From the maximum pressures they calculated the maximum temperatures, arriving at results for hydrogen and carbonic oxide mixtures similar to those obtained by Bunsen and by Mallard and Le Chatelier. But whereas Bunsen attributed the defect of pressure to the inability of two-thirds of the gases to combine at the temperature reached, the French chemists attribute this defect of pressure to the great increase of the specific heats of the gaseous products of combustion. On the other hand, Dugald Clerk contends that in an explosion of gases, combustion is not completed instantaneously, the products of combustion are cooling while the unburnt particles are still combining, and therefore the maximum temperature reached never coincides with the theoretical temperature calculated for instantaneous combustion. The spreading of the flame throughout the vessel, *i.e.*, the inflammation of the whole mass of gas, is not coincident with the moment of maximum temperature and pressure. On exploding mixtures of coal gas and air, and of hydrogen and air, in a closed vessel, and registering the pressure with a Richard's indicator, Clerk comes to the conclusion that neither dissociation of the products of combustion, nor a rise in the specific heats, can account for the fall of the observed pressures below those calculated. This fall must be accounted for by the gradual progress of the combustion. Concerning the rise in the specific heat of carbonic acid there can, the author thinks, be little doubt that it really exists. Regnault and Wiedemann both found a distinct increase at constant pressure between 100° C. and 200° C. The author has determined the specific heat of carbonic acid at constant volume at 100° C., 200° C., 300° C., and 400° C., and finds a steady rise in the constant.

On the other hand, the facility with which carbonic acid breaks up under the influence of electric discharges indicates that, as its temperature is raised, work is done in loosening the chemical bonds. Of the fact of the partial dissociation of carbonic acid and steam at the temperature of the detonation-wave, the author has found direct proof in the unburnt gases left on cooling. He believes that in the detonation of gases, *i.e.*, in the explosion-wave itself, the temperature and pressure reached are largely influenced both by dissociation and by a preliminary increase in the specific heats. In the earlier phases of the explosion, and in mixtures where detonation does not occur (such as mixtures of coal-gas and air) he believes that the gradual progress of the combustion also largely influences the temperature and pressure. No pressure diagram has been obtained which gives evidence of Bunsen's successive partial explosions.

Influence of Aqueous Vapour on Combustions.—It was while the author was repeating Bunsen's work on the division of oxygen in explosions that he hit on the curious phenomenon presented by a mixture of dried carbonic oxide and oxygen. He found that the dried mixture would not explode under the action of a spark which readily kindled the moist mixture, and that a flame of dried carbonic oxide burning in moist air is extinguished when the air is dried round it. If carbonic oxide is only oxidised through the intervention of steam—and carbon, sulphur, and phosphorus are curiously inactive when heated in dried oxygen—may it not be that *all* oxidations are effected by the action of water? He agrees that, in the burning of carbonic oxide in air, the water gives up its oxygen to the carbonic oxide and the liberated hydrogen reforms water by combining with the oxygen of the air—the hydrogen thus playing the part of "the carrier of oxygen." But he has not yet become (to adopt the expressive language of to-day) "a whole hogger" with regard to the influence of water vapour. Cyanogen can burn without requiring the presence of any water that can be detected; if you add any appreciable quantity you *retard* the oxidation. When a mixture of hydrogen and oxygen, or of hydrogen and chlorine, is *sparked*, the explosion travels more quickly when the mixture is dried than when it is moist. But there are distinguished chemists who take other views. Armstrong's view is that chemical change and electrolysis are interchangeable equivalent terms, or that a chemical action is *reversed* electrolysis. There is no such thing as a simple change between two substances. Oxidation is an indirect process taking place in a circuit of the oxidizable substance conducting water and oxygen. For example, the burning of hydrogen by oxygen is brought about *through the water, thus*:—

$$\text{(i)}\quad H_2 \mid OH_2 \mid O_2 = H_2O \mid H_2O_2$$

The peroxide formed being either decomposed by heat, or acting on more hydrogen through water:

$$\text{(ii)}\quad H_2 \mid OH_2 \mid O_2H_2 = H_2O \mid H_2O \mid H_2O$$

In the burning of carbonic oxide Armstrong originally suggested:—

$$\text{(iii)}\quad \begin{matrix} CO \\ CO \end{matrix} \left| \begin{matrix} OH_2 \\ OH_2 \end{matrix} \right| \begin{matrix} O & CO \\ = & \\ O & CO_2 \end{matrix} \left| \begin{matrix} H_2O \\ H_2O \end{matrix} \right.$$

But in his latest paper, Armstrong suggests that water acts directly on carbonic oxide producing formic acid:—

$$\text{(iv)}\quad CO + H_2O = HCOOH$$

And the formic acid, either directly or indirectly gives carbonic acid and hydrogen. Now it will be observed that in equation (iv) Armstrong allows that a direct action may take place between carbonic oxide and steam. The author is puzzled to understand why Armstrong cannot allow that they should re-act directly to form carbonic acid and hydrogen, a reaction which seems to be the simplest explanation of the facts. With regard to the union of hydrogen and oxygen, the author has been unable to detect that water-vapour exerted any influence once the explosion was started by a spark. But Brereton Baker has shown that the very highly purified and dried gases do not explode in contact with a red-hot wire, although gradual union takes place. *Water*, therefore, is not the necessary "go-between," but, as Armstrong says, there must be *conducting* or *dirty water* present. Consequently, equation (i) requires another term in it, for only a molecule of pure water has been included. This matter becomes important when we apply Armstrong's equations to the reactions in the explosion-wave. But when it is laid down that "dirty" water is necessary for the combustion of hydrogen, one feels tempted to ask whether some "dirty" gas would not do equally well? Most "pure" hydrogen contains some hydrocarbon, and as Dr. Bone has shown, hydrocarbons are more easily oxidized than hydrogen. Baker has certainly shown that pure hydrogen ignites at a higher temperature than was supposed, but he has not shown that water, either pure or dirty, is necessary to propagate an explosion in pure electrolytic gas. Dr. Bone, in an important series of experiments, has recently shown that, in the slow oxidation of methane and other hydrocarbons by oxygen below a red heat, that water and aldehyde are gradually formed:—

$$CH_4 + O_2 = CH_2O + OH_2$$

The formaldehyde so formed may break up into carbonic oxide and hydrogen, or be oxidized to oxides of carbon and steam. The oxygen, according to Dr. Bone, divides itself between the hydrogen and the residue of the hydrocarbon, and at no stage of the gradual oxidation is free hydrogen or free carbon evolved. Armstrong considers that Bone's results bear out his views that the oxidation of hydrocarbons is effected by a series of successive "hydroxylations"—the oxygen being transferred electrolytically across "conducting" water:—

$$\begin{aligned} CH_4 \mid OH_2 \mid O_2 &= CH_3OH \mid H_2O_2 \\ CH_3OH \mid OH_2 \mid O_2 &= CH_2(OH) \mid H_2O_2 \\ CH_2(OH)_2 \mid OH_2 \mid O_2 &= CH(OH)_3 \mid H_2O_2 \text{ etc.} \end{aligned}$$

The formaldehydrol, produced at the second stage, breaks up into formaldehyde and water:—

$$CH_2(OH)_2 = CH_2O + OH_2$$

and the formaldehyde is oxidised to formic acid, which in turn yields carbonic acid. It will be observed that in Armstrong's scheme the first oxidation product of a hydrocarbon is an alcohol. Dr. Bone has, however, searched for an alcohol in vain. But Professor Armstrong does not apply his electrolytic theory to systems at moderate temperatures only. He also applies it to explain the chemistry of the explosion-wave at enormously high temperatures. There is no reason why temperature should make any difference, he says. It is here that the author differs from him. When ethylene is exploded with its own volume of oxygen, we have seen that carbonic oxide and hydrogen are formed in equal volumes; but, according to Armstrong, hydroxy-ethylene should first be formed, and this might yield acetylene and water, and the acetylene would then be converted in the same way to carbon and water :—

$$\begin{array}{l} C_2H_4 \mid OH_2 \mid O_2 = C_2H_3OH \mid H_2O_2 \\ C_2H_3OH \quad\quad = C_2H_2 + H_2O \\ C_2H_2 \mid OH_2 \mid O_2 = C_2HOH \mid H_2O_2 \\ C_2HOH \quad\quad = C_2 + H_2O \end{array}$$

For the explosion of cyanogen with its own volume of oxygen Armstrong gives the following cycle :—

$$\begin{array}{l} C_2N_2 \mid OH_2 \mid O_2 \quad = NCO{\cdot}CN \mid H_2O_2 \\ NCO{\cdot}CN + H_2O_2 = NCO{\cdot}CON + H_2O \\ CO{\cdot}CO \\ \;\;\| \quad\; \| \quad\quad = 2\,CO + N_2 \\ N = N \end{array}$$

On the rate of Explosion in Gases.—The author's first attempt to measure the rapidity with which an explosion is propagated through gases, was due to his desire to test the theory he had been led to regarding the mode of burning of carbonic oxide. He thought, and still thinks, that if the burning takes place through the direct interaction of the carbonic oxide and steam molecules, or even if it is necessary that molecules of carbonic oxide steam and oxygen should all be in contact at the same time, then it must follow from the Law of Mass that if the steam is increased beyond the amount just required for combustion, the rapidity of the reaction will be increased. He found that it was so, but also found that the rapidity of explosion of moist carbonic oxide and oxygen had been enormously under-rated. Meantime, M. Berthelot and M. Le Chatelier, working independently of each other, had also examined the rates of explosion of gases. M. Berthelot made the important discovery that the rate of explosion rapidly increases from its point of origin, until it reaches a maximum which remains constant, however long the column of gases may be. The rate of explosion thus forms a new physico-chemical constant, having important theoretical and practical bearings. The name "L'Onde Explosive" was given by Berthelot to the flame when propagated through an explosive mixture of gases at the maximum velocity. Berthelot next enunciated a remarkable theory to explain the propagation of the explosion-wave. He considered that it travelled at the mean rate of translation of the heated molecules formed in the explosion before they had time to lose any of the heat of chemical combination. This theory means that the explosion is propagated by the successive collision of the molecules against each other, just as a sound wave is propagated through air. The author does not agree with Berthelot's method of calculating the theoretical velocity of the explosion-wave, and has modified his formula, taking into account the fact that the wave must be propagated, not only by the burnt but equally by the unburnt molecules (with which the former exchange velocities) and that, therefore, half the unburnt molecules are heated by collision before they are burnt. The author then calculated at what pace a sound-wave would travel through such a heated mixture of gases, and found an extraordinary close agreement between the rates so calculated and the velocities of explosion measured by the chronograph in a long tube. He has particularly studied the "damping" effect of inert gases on the propagation of the wave, and finds the retarding effect to vary directly with the volume and density of the inert gas added. Conversely, he argues that if a gas added to an explosive mixture retards the wave by an amount which varies directly with its volume and density, then such added gas is inert as far as the primary action in the wave front is concerned; and if it is found to be chemically altered, then such change is due to a secondary reaction taking place behind the wave-front. As an illustration of this work he refers to the rates of explosion of cyanogen with oxygen, alone, and when diluted :—

Mixture	$C_2N_2 + O_2$	$C_2N_2 + 2O_2$	$C_2N_2 + 3O_2$
Rate	2728	2321	2110
Mixture	—	$C_2N_2 + O_2 + N_2$	$C_2N_2 + O_2 + 2N_2$
Rate	—	2398	2165

Cyanogen mixed with its own volume of oxygen burns to carbonic oxide and nitrogen; the rate at which the flame is propagated is far higher than when two volumes of oxygen are used and the final products are carbonic acid and nitrogen. This in itself is an argument in favour of the view that the carbon burns directly to carbonic oxide in the wave-front. But stronger evidence on this point is obtained by comparing the explosion rate of these gases (1) when fired with oxygen sufficient to burn the carbon in them to carbonic acid, and (2) when nitrogen is substituted for the oxygen in excess of that required to burn the carbon to carbonic oxide. Oxygen added to electrolytic gas hinders the explosion more than nitrogen. In precisely the same way oxygen added to a mixture of equal volumes of cyanogen and oxygen

hinders the explosion more than the same volume of nitrogen. The conclusion we must come to is that the oxygen added to the mixture expressed by the formula $C_2N_2+O_2$ is an inert (so far as the propagation of the explosion-wave is concerned), as oxygen added to the mixture expressed by the formula H_2+O. The same phenomena occur in the explosion of marsh gas, ethylene, and acetylene. In all these cases the substitution of nitrogen for the oxygen required to burn the carbon from carbonic oxide to carbonic acid *increases* the velocity of the explosion. These facts seem only consistent with the view that the carbon burns directly to carbonic oxide, and the formation of carbonic acid is an after-occurrence. The author's sound-wave formula has predicted results which have been found uncommonly near the truth. Compare the following rates, in metres per second, calculated and found for very different mixtures of gases :—

Mixture.	Calculated Rate.	Found Rate.
$8\,H_2 + O_2$	3,554	3,535
$H_2 + 3\,O_2$	1,740	1,712
$2\,H_2 + Cl_2$	1,832	1,849
$C_2N_2 + O_2$	2,725	2,728
$C_2N_2 + O_2 + 2\,N_2$	2,166	2,163
$C_2H_4 + 2O_2 + 8\,N_2$	1,727	1,734

In making the calculation given above for the hydrogen and oxygen mixtures, the decomposition of the oxygen molecule has been taken into account. If the change is determined on simple collision of the molecules, we must assume in the explosion of electrolytic gas that an oxygen atom is liberated :—

$$H_2 + O_2 = H_2O + O$$

The wave will then be propagated partly by the burnt gas (steam), partly by half-burnt gas (steam, hydrogen, and atomic oxygen), and partly by the unburnt gas (hydrogen and oxygen). The mean density of this mixture of gases would be seven referred to hydrogen. Now it is almost inconceivable that the rates of explosion could be given by any one formula for such very different mixtures of gases unless the mode of propagation were similar in each case. How could this happen if we suppose, with Armstrong, that in each case there is formed a different series of intermediate "compatible compounds" which in turn break down? Again, the fact that heavy inert gases damp down the explosion-wave, just as they do a sound-wave, seems a strong argument that the explosion-wave and the sound-wave are propagated in the same way. In the one case of explosion, where the chemical change seems to be indirect, viz., the explosion of moist carbonic oxide and oxygen, the sound-wave formula does not apply. The rate of explosion increases with the addition of steam until the latter constitutes above 5 per cent. of the mixture. In the case of other explosions, where the sound-wave formula does apply, viz., with hydrogen and oxygen, hydrogen and chlorine, cyanogen and oxygen, etc., the addition of 2 per cent. of steam appreciably diminishes the rate. The author sees in these facts strong reasons to doubt whether Armstrong's theory can be applied to explosions. The author then proceeds to an explanation of methods used and results obtained by the application of photography to explosion flames, and to the results obtained by Oettingen and Gernet and himself. Photographs taken of the whole flame starting from the firing wire show that the flame starts slowly, gathers pace and intensity, and finally sets up the explosion-wave which proceeds with a perfectly uniform rate and intensity. The explosion-wave starts suddenly, throwing back a wave he calls the wave of "retonation," and leaving a dark space of cooled gas at the point of starting (Fig. 1). But when, as is usual, the gases are fired by wires sealed into a tube a few inches from one end, the flame which travels to the *near* end sends back a reflected wave which travels through the ignited gas more quickly than the original flame. This second (reflected) wave may catch the primary flame and modify its motion and intensity (Fig. 2). The rapidity of inflammation and the quickness with which the explosion wave is set up largely depend on the

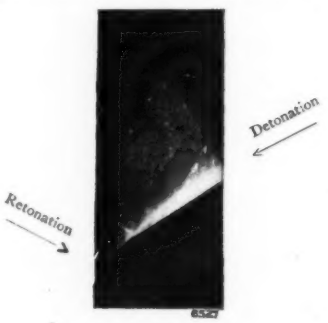


FIG. 1.

FIG. 2.

point of ignition, and whether the flame can get this "kick-off" from the end of the tube. When the gas is fired *at the end* the flame travels much more slowly. This is a point which he thinks deserves the attention of all those designing internal-combustion gas-engines. The true explosion is not invisible, the flame can be photographed throughout its whole course. But in the initial stages the flame travels slowly, and is of small intensity. It only becomes brilliant when the explosion-wave is set up, or when a retonation or powerful reflected wave traverses the burning gases. In the initial stage the combustion is taking place slowly, only a few among the total collisions occurring are chemically fruitful; in the detonation or explosion-wave the combustion is taking place with intense rapidity, the great majority of collisions being chemically fruitful. The explosion-wave may be made to meet a flame in the initial stage. It can be seen to pass through the already ignited gases with hardly any check on its velocity and intensity. It is perfectly evident from this, and from a study of the reflected waves, that combustion cannot be complete when these waves traverse the gases. The spread of the flame is not synchronous with the attainment of maximum temperature or with complete combustion. The reflection of the sound-waves through the burning gases give rise to many nearly parallel "secondary" waves. Their source can readily be traced by photography; there is no need to invoke any of Bunsen's "successive partial explosions" to account for them. The author is now trying to photograph the movements of flame in a gas-engine cylinder, while the pressures are recorded by an indicator. In conclusion, he states that the burning of a highly-explosive gas mixture is one of the best means of developing light from gas. Coal-gas and air will intense, not "detonate," but coal-gas and oxygen will do so. Industrial (50 per cent.) oxygen can now be made fairly cheaply by the fractional distillation of liquid air. It has been made on the large scale at a cost of about 5*s.* per thousand feet; the author sees no reason why it should not be made for half that price. Coal-gas fed with such oxygen may be made to burn on a zirconia mantle and give a light roughly of 200 candles for a consumption of 2 cubic feet of coal-gas per hour. Is not this something which would have appeared chimerical a year or two ago, and yet it is only one of the developments which must flow from a study of the mechanism of combustion of gases. —*Lecture before the Inst. of Gas Engineers. Report Gas World. June 11th, 1904.*

The Specific Heat of Superheated Steam. **R. H. Smith.** In recent years occasional experiments have shown that the specific heat of superheated steam is greater than the value ·48 obtained by Rankine. Professor H. Lorenz has recently carried out a series of experiments ranging over the whole range of pressures and temperatures used in engineering practice.* Owing, however, to the irregularities of the combinations of pressure drop and temperature fall, no certain law can be recognised as running through the numerical results given, and Professor Lorenz himself only remarks that "the specific heat increases with the pressure, and decreases with the temperature as the condition departs more from the saturated condition." For low pressures ·48 seems to hold good; while for high pressures ·6 is more nearly true. In this Paper the author has effected a graphic interpretation of Professor Lorenz's results (Fig. 1). This is a plan with pressures as abscissæ and temperatures as ordinates. If at right angles to the plane of this chart were erected at each point an ordinate whose height represented the specific heat of steam in the pressure-temperature condition denoted in the plan, there would be obtained a curved surface which would be a complete diagram of steam specific heat. Contours of equal levels on this surface would join up all points at which the specific heat is the same The full-line curves on Fig. 1, marked ·48, ·5, etc., are such contours. The straight lines sloping slightly from the vertical, and each with two arrow-heads upon it, show the courses of each of the tests recorded; the upper end of the line denoting the pressure and temperature of the steam at the entrance to, and the lower end, at the exit from, the calorimeter. The middle point of each line is marked by a crossed circle, and the specific heat obtained in each experiment, being the average specific heat through this range of pressure and temperature, is taken as being the value of the specific heat at the point denoted by the circle. It will be seen that these tests were carried out at each of the three approximate pressures—4, 7, and 9 atmospheres and two at 2 atmospheres—and for each series a curve is drawn in long-dash lining through the middle point of each of the three tests. Next, for each series, a vertical base-line is chosen, from which the calculated specific heats are plotted horizontally. Through these plotted points are drawn the curves in short-dash lining. These may be considered as vertical sections through the surface of the specific-heat model along the long-dash plan lines. The specific heat scale of the short-dash curve is marked at intervals along each. Each of these curves passes through, say, ·55 on this scale, at a certain temperature. Its crossing-point is now projected horizontally on to the long-dash curve, and the point thus obtained on the latter curve is a point on the ·55 specific-heat contour in the pressure-temperature chart. The heavy-line contours are thus drawn. Owing to the few points for which experimental results were obtained, the curves must only be looked upon as being approximate. Nevertheless, the chart gives a clear idea of the general trend of the law of variation. This is seen still more clearly from the small scale of the diagram, in which the construction lines are omitted, the saturated-steam curve being also shown. At low pressures—2 atmospheres—close to the saturated condition, the specific heat probably rises to between ·6 and ·7, and falls off rapidly with rise of temperature at first, more slowly afterwards. At higher pressures,

* An account of these experiments, with a sketch of the apparatus used, was given in these Abstracts for July, 1904.

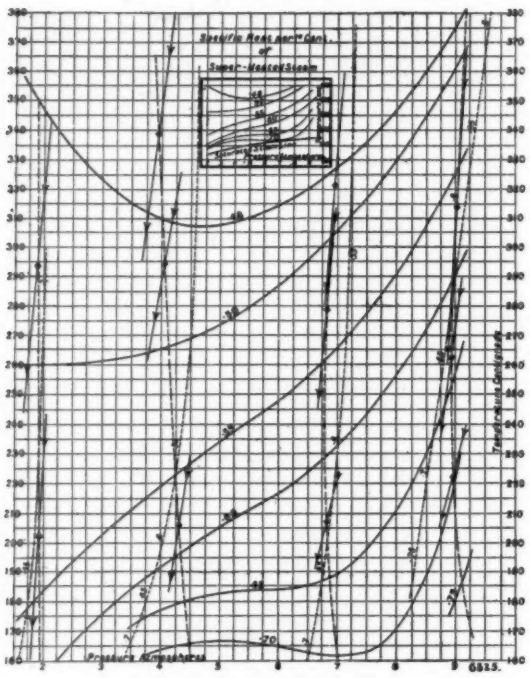


FIG 1.—SPECIFIC HEAT OF STEAM.

such as 9 or 10 atmospheres, the specific heat is probably about ·8 near to the saturated condition. Here the contour-lines tend to become very steep on the diagram, so that a large increase in temperature, with a slight increase in pressure, does not result in any change of specific heat. The crowding together of these contour-lines becomes more pronounced as the "critical" point is approached, the steam specific heat close to the saturated condition approaching the value unity. Just beyond this point, still in this condition, it must be identical with the specific heat of water at the same temperature and pressure; and as the specific heat of water increases with its temperature, it must be considerably above unity near the critical point. — *The Engineer, Vol. XCVIII, No. 2532,* pp. 25 and 26.—*A. H. G.*

Experiments on the Utilisation of Peat. **Dr. L. C. Wolff.** The experiments recorded in this Paper were made on behalf of the Prussian Government, with a view to ascertaining whether the process devised by Mr. Martin Zeigler would be suitable for a utilisation of the German peat moors, which cover an area of 500 German square miles. The carbonisation oven designed by Zeigler for producing from peat a high-grade fuel, is an upright retort of an oval cross-section, the lower part of which is made of fire-proof brickwork and the upper part of cast-iron. The charge consists of peat previously dried until it contains only about 30 to 40 per cent. of water, this moisture being distilled by the heat of gases passing through coils which surround the retort, while the peat sods are sinking from above downwards, to be discharged there in a charred condition. The volatile substances freed are separated from the remaining components by cooling them on large surfaces, while the gaseous matter remaining in the coil is burned with atmospheric air for firing the oven. The firing therefore occurs along with the process itself; and in the case of the peat being sufficiently dry, a sufficient quantity of gas will be produced for generating the power necessary for the manufacturing stage The experiments were made on a very large scale, 500,000 kgs. of peat being worked on, the Oldenburg factory, including five Zeigler ovens, being used. The distillation gases, issuing laterally from the oven, were drawn by an exhauster through a condensation battery, consisting of syphon-shaped sheet-metal pipes about 50 cm. in diameter, and including a sheet-metal box connected below, the surface cooled by air being about 300 sq. m. An explosion safety device was adopted in the shape of a small shallow gas reservoir, and an ordinary steam ejector was used for overcoming any resistances in the further condensation and tube ducts to the heating channels. The fire gases produced in the latter traversed a chimney about 35 m. in height and 1 m. in clear width, whence they escaped into the open air. Into the same chimney issued the flue of a two-tube boiler, of 50 sq. m. heating surface, heated either with excess gases not required for the ovens themselves or with peat refuse. The boiler supplied steam for the ejector and for the operation of the exhauster, the tar water and tar pumps, as well as for the adjoining station in which the purification of paraffin and the distillation of tar were conducted. The tar water and tar, after being deposited in the condensers from the gases, pass continuously through syphon valves into a pump reservoir, from which they were conveyed into a receptacle placed on a higher level, where the tar, being lighter, readily separated from the water, provided it was maintained at a temperature of at least 30 degs. Cent. This was obtained by conveying live steam into the tar water. The oven terminated below in hoppers, fitted with screw locks, on opening which the incandescent peat briquettes were discharged into a tipping

cart below, in which they were extinguished with water, and then conveyed to the factory yard to be completely cooled there. The following substances were recovered from the tar water:—methyl alcohol, ammoniac (being introduced into diluted sulphuric acid and crystallised as ammonium sulphate), and acetic acid (by means of lime milk as calcium acetate). A treatment of the tar yields both light and heavy oils, paraffins, phenols, and asphalt as a distillation residue. The total consumption of peat (including 0·7 per cent. wood) was 523·7 tons, with a mean percentage of water of 31 per cent., amounting to 162·3 tons The daily consumption was 36·11 tons, corresponding with a consumption of 1,504 tons per hour. The tar water amounted to 245·7 tons with a specific gravity of 1·0045, and the tar amounted to an aggregate of 23·53 tons of 0·98 specific gravity. The peat briquette produced contained an average of 4·3 per cent. of water, and worked out at 948 wagons per day, corresponding with 10,265 kgs., while the output per second was as high as 0·119 kgs. The heating gas generated amounted to 37 per cent., and after being diluted with air entering simultaneously, to 57·3 per cent. of the weight of the peat. The weight of the undiluted heating gases was 1·006 grams per litre, and in the diluted state 1·110 grams per litre. The flame temperature with the combination of the heating gases was found to be 1,140 degs. Cent., while the calculated value was 1,033 degs. Cent. The excess of air in the combustion amounted to 185 per cent. The upper heating value of the fire gases was 2,877 heat units per cubic meter, while the loss in the chimney was 25 per cent. of this figure. The mean temperature of the heating gases in the main duct was 47 degs. Cent., and the average gas pressure 14 mm. of water column. The mean temperature of the oven-flue was 302 degs. Cent., while the temperature in the pit of one of the ovens varied between 200 degs. and 620 degs. Cent. The following table gives the composition of the products:—

PEAT				100·0:
Peat fuel	27·3 pure; actually			28·4
Tar	4·5	,,	,,	4·5
Tar water	31·2	,,	,,	46·6
Heating gases	37·0	,,	,,	57·3
	100·0			136·8

TAR		100·0:
Light oils therein		45·0
Heavy ,,		15·0
Paraffin		7·0
Phenol		30·0
Asphalt		3·0
		100·0

As regards the amounts of heat available, these were:—

	Per cent. of heat in the Peat.
In the Peat fuel	56·8
,, Tar	11·1
,, Heating gas	43·5
,, Wood spirit	0·5
,, Acetic acid	0·4
,, Ammoniac	0·9
	112·5

The economic side of the question is represented in the following tables, where the market prices of the products derived from 10,000 kgs. of peat are recorded:—

kgs.		Market price per kg.		Marks.
2,730	Peat fuel	6	=	163·80
270	Gas oils	36	=	97·20
30	Paraffin	75	=	22·50
130	Phenols	180	=	234·00
20	Asphalt	15	=	3·00
34	Methyl alcohol	125	=	42·50
31	Ammonium sulphate	34	=	10·50
50	Calcium acetate	21	=	10·50
3,295	Products			584·00
10,000	Peat costs			50·00
	Balance			534·00

According to the estimates of the author, the factory giving an output of about 10 tons of peat briquettes per day would allow a net profit of about 700 marks per working day.—*Zeitschrift des Vereines Deutscher Ingenieure, Vol. XLVIII, No. 24*, pp. 887–892.—*A. G.*

Iron-Ore Mining in Scandinavia. **W. Fischer Wilkinson.** The author exhaustively deals with the ore deposits of Sweden and Norway. Of special interest are the Dunderland deposits, which illustrate the application of modern methods of concentration to low-grade ores. The plant in course of erection, designed by T. E. Edison, is estimated to handle 1,500,000 tons of ore per year. The deposits will, in the first instance, be opened out as quarries, and operations conducted by means of steam shovels capable of loading up to 500 tons per hour. Concentration will be effected magnetically in the dry way and conducted in stages, magnetite being removed first and then hematite. The various crushing and concentrating methods will be automatic, and conveyance effected by means of belt-conveyors. The 1,500,000 tons of ore mined are estimated to yield 750,000 tons of clean ore having a metallic content of 65 per cent. iron. The fine concentrates will be briquetted prior to shipment.—*Inst. of Mining & Metallurgy, and Iron & Coal Trades' Rev., July 1*, pp. 27–29.—*P. L.*

Testing Steels for Electrical Purposes. **C. E. Skinner.** In commercial routine testing, two methods, known as the transformer and armature methods, have been found satisfactory. In the first method the test sample consists of about 10 lbs. of transformer-plate punchings built up in the same manner as when used in the transformer. For convenience in handling and winding the test sample, a block carrying the coil is used, the block being divided and the wires of the coil continued between the two parts by means of mercury cups and contacts. Hence built-up samples or plates which are not split may be used and placed on the testing-block with the winding in position in a few seconds. The routine tests on such samples consist in measuring by means of a wattmeter the total losses at a given induction and frequency. For special tests, the induction, frequency, wave-form,

and pressure on the sample are varied as desired. This test is employed in determining the quality of each batch of steel, the success of annealing, and for determining ageing in all classes of material. In the armature method the samples consist of armature punchings, which are revolved in a standard form of dynamo-field; the measurements being made by means of a spring dynamometer. The general plan of the apparatus is as follows: A variable-speed direct-current motor has a shaft extension on which the sample is mounted. The speed is read in terms of voltage across the terminals of a small magneto belted to the motor-shaft. The test sample is revolved in a field having specially wound field coils and adjustable pole pieces. The extension-shaft on which the test sample is mounted carries a spring dynamometer having a special device for reading the deflection when the sample is in motion. The sleeve carrying the sample is provided with heavy flanges, and may be placed in a hydraulic press in order that any degree of pressure may be maintained on the sample during the test. This apparatus offers a convenient method of studying the variation in armature losses due to differing conditions, such as pressure, insulation between sheets, variation in induction, etc.—*Amer. Soc. for Testing Materials* and *Iron Trade Rev., Vol. XXXVII, No. 25*, p. 44-46.—*P. L.*

Some Examples of the Irregular Distribution of Sulphur in Pig Iron. **John J. Porter.** The table shows the variation of sulphur in the cross-section of several pigs, each one being from a different cast of foundry iron.

PIG IRON.

	A.S. %	B.S. %	C.S. %	D.S. %	E.S. %
Hole No. 1, top	0·115	0·058	0·066	0·165	0·166
,, No. 2	0·125	0·058	0·061	—	—
,, No. 3	—	0·052	0·061	—	—
,, No. 4	—	—	0·084	—	—
,, No. 5	—	—	0·059	—	—
,, No. 6, bottom...	0·040	0·030	0·029	0·175	0·103

—*Indianapolis Conv. Amer. Foundrymen's Assoc., June, 1904.—P. L.*

Carbon. **F. C. Everitt.** Subject to variation in size and the presence of certain other elements, the strength and hardness of iron castings are determined by the amount of combined carbon. This control is shown in the following properties:

Extra soft grey iron ...	0·08	per cent.	combined carbon.
Ordinary soft grey iron	0·15	,,	,, ,,
Iron of maximum tensile strength	0·50	,,	,, ,,
Iron of maximum transverse strength ...	0·70	,,	,, ,,
Iron of maximum crushing strength	1·00	,,	,, ,,

—*Indianapolis Conv. Amer. Foundrymen's Assoc., June, 1904.—P. L.*

Alloy Steels. **Wm. Metcalf.** As a rule the earlier type of self-hardening steels contained from 2 to 3 per cent. manganese, 4 to 6 per cent. tungsten, and a fairly high content of carbon. In modern high-speed steels the carbon has been reduced to below 1 per cent., manganese from 3 per cent. to traces, and tungsten increased to amounts in some cases as high as 20 per cent. Three analyses of these steels are given as follows:—

	1	2	3
Tungsten ..	9·09	18·48	..
Chromium ...	2·83	2·90	...
Carbon ...	0·60	0·79	0·66
Manganese ...	trace	0·33	0·22
Molybdenum .	...	...	9·65

—*Amer. Soc. for Testing Materials* and *Iron Trade Rev., Vol. XXXVII, No. 25*, pp. 67, 68.—*P. L.*

Modern Methods of Steel-Casting. **J. Horner.** In this, the first of a series of articles, the author discusses the "shrinkage" and "drawing" of steel. As remedial measures various forms of "filleting" are suggested for the former evil and "feeding-heads" for the latter one.—*Technics, Vol. II, No. 7*, pp. 38-42.—*P. L.*

High-Speed Operation of Normal Railways. **Prof. von Borries.** The successful trials carried out by the "Studiengesellschaft für Elektrische Schnellbahnen" on the Marienfelde-Zossen military railway, in which speeds as high as 210 km. per hr. were attained, far surpassed records hitherto obtained with steam locomotives. As to whether such speeds would be suitable for the economical operation of railways or not, experience alone will be able to determine. After giving an historical survey of the above trials—an account of which was published in these columns in December of last year—the author proceeds to discuss the steam locomotive high-speed experiments recently undertaken by the Prussian railway department on the same line with a view to obtaining comparative data as to both methods of operation. The steam locomotive has been greatly improved in recent years, so that now much better performances are possible with an equal consumption of energy. In Germany, moreover, much has been accomplished by the adoption of compounding and

superheating. Further, the efficiency of a locomotive within certain limits is augmented by an increase in speed, the most favourable conditions being reached with a velocity of about 100 km. per hr. From a discussion of the design of a four-cylinder high-speed locomotive as used in connection with the recent trials, the author infers that 1,400 h.p. to 1,750 h.p. output, and 70 to 80 tons weight in working order, may be taken as an average for the actual possibilities of steam locomotives. He does not think it practicable to haul small trains with these big locomotives, a minimum of 180 seats and a weight of about 240 tons having to be allowed for. Whenever an additional coach or a dining-car has to be added, a weight of 280 tons will be required. It would not be feasible to diminish the comfort of passengers with a view to the better utilisation of space, the gain in time afforded by an increase in speed of 10 km. to 20 km. being too unimportant to allow, for instance, dining-cars to be done away with. Locomotives of 1,100 h.p., 1,400 h.p., and 1,750 h.p. would be able to haul such trains in good weather at speeds of 100 km. to 110 km. and 120 km. respectively; or, on a commercial basis, and over long distances of, at most, 90 km. 100 km., and 110 km. An increase of the output of the locomotive as high as 650 h.p. would result only in an increase of 20 km., showing that steam locomotives with these speeds have practically reached the limit of their economical possibilities. It seems doubtful whether it would pay to expend 350 additional h.p. with a view to increasing the average speed from 100 km. to 110 km. The two systems of operation accordingly have quite different aims. The tendency towards an increase in the speed of steam railways has a quite different importance from electric high-speed operation, the object of which is a more frequent communication with considerably augmented speeds. The advantages obtained by the latter method permits of a considerable increase in the traffic density. The author does not advise the conversion to electric high-speed operation for some time to come on the ground of expense. The greater part of the cost of operation corresponds to the motive power; and this, being mainly dependent on air resistance, should be diminished as far as possible by adopting sharp wedge-shaped ends both at the back and front of the train, and avoiding as far as possible any projection and discontinuity in the lateral surfaces. The trains should not be too small, lest the air resistance, motive power, and cost be too high as compared with the capacity of the train. Trains including three 6-axle cars, with 100 seats and luggage compartments at the front and rear, would appear to be suitable. Such trains would have at full load a weight of about 200 tons, and with a speed of 160 km. would necessitate a motive power of 1,260 kg. and an output of 750 h.p. On account of the considerable shortening of the journey, a buffet compartment would advantageously replace the dining-car. As regards the question as to whether electric operation should be introduced on existing railways, or if new high-speed railways should be constructed, necessitating a considerable outlay and absorbing most of the passenger traffic of existing railways, the author thinks that the latter alternative would pay only in the case of the existing line being so occupied by other trains as to leave no room for high-speed traffic. Special investigation will be necessary in each case to ascertain whether a high-speed traffic may be combined with the existing slow passenger and goods traffic. The author does not think it necessary to provide special two- or three-track lines without any intermediate stations, switches, level crossings, etc. Speeds of 150 km. would be quite sufficient and suitable, as the gain afforded by an increase of from 150 to 200 km. would not be great enough to pay for the increase of about 80 per cent. (corresponding to the square of the speed) in cost and difficulty of operation. On the other hand, existing superstructures with rails of 41 kg. per m., as used on Prussian normal railways, would be amply sufficient, the more so as the load on the car axles would be less in future. Guiding rails do not seem to be necessary. Level crossings, according to the author, would hardly afford more difficulty than they do now, and the long electric cars sharpened at the front would cut through any obstruction on the track far better than any locomotive, while affording an efficient protection against derailments. Prof. von Borries suggests using the Berlin–Potsdam–Wildpark normal railway for introducing electric operation into practice immediately, replacing the greater part of the suburban trains by double the number of electric trains, when a speed of 120 km. would be sufficient to reduce the journey to about half the time now occupied.—*Zeitsch. Vers. Deutsch. Ing., Vol. XLVIII, No. 26*, pp. 949–959, *June 25, 1904.*—*A. G.*

Commercial Practicability of Electric Traction by Surface Contacts. **C. E. C. Shawfield, A.M.I.E.E.** The author, in this Paper, makes certain comparisons between the overhead system—so universally adopted in this country—and the surface-contact system which has been under his control for the past 2½ years at Wolverhampton. The equipment of the track at Wolverhampton was undertaken by the Lorain Steel Company of America, and as the design and general arrangement of this system is well known, the author does not give any technical description of the system itself, but compares the respective merits of the overhead and surface-contact systems. *Safety.*—In comparing the respective advantages from the point of view of safety of the overhead and surface-contact systems it is evident that only one source of danger need be seriously considered—namely, that of electric shock, as practically all other risks are common to electric traction. In the case of the surface-contact system, the only portion of the apparatus exposed to the public from which a shock could be obtained is the metal stud in the centre of the track, and this can only become or remain alive (except when it is covered by a car) in the event of some failure of, or defect in, or damage to, the mechanism which operates it. The actual value of this risk may best be

estimated in the light of actual experience, and the author has therefore analysed the records of defective boxes during the past twelve months, and has extracted the following particulars: viz., that a total of 109 boxes were found more or less alive, 59 of which were alive at an e.m.f. of over 50 and under 500 volts. The presence of a metallic stud in the street charged at a pressure of 500 volts does not, in the author's opinion, imply that the stud is capable of transmitting a dangerous shock to any animal or person standing thereon, as, owing to the comparatively high resistance of the conducting path formed by the charring of the interior of the cup, the quantity of current that can pass is exceedingly small. In only one instance has a serious result followed on a shock received from a live stud, when a sheep and a dog were electrocuted. With reference to the cups damaged by short circuits, recent experiments made by the author show that the degree of damage entirely depends upon the time element of the circuit breaker controlling the main feeder. When the traction switchboard was installed at the power station the possibility of the adoption of a surface-contact system had not been considered, and the circuit breakers for the tramway feeders were specially designed to give a comparatively slow break. Experience has shown, however, that this is the worst type of apparatus for use, and the author is now replacing the original type with others of a new type, and he has every reason to believe that the alteration will very greatly reduce the number of defective boxes in future. In so far as the question of safety is concerned, the author concludes that the balance of advantage lies with a well-designed surface-contact system. *Reliability of Operation.*—It is very difficult to compare the overhead and surface-conduit systems, owing to entire lack of statistical information regarding numbers of journeys lost through the failures of the overhead electrical equipment. The author has, however, kept strict record of every delay occurring on the Wolverhampton system, which shows that out of 173 car-miles lost in 12 months due to defects in the surface-contact system, 27 were due to the track, and 146 to the cars themselves; this working out to an average of 3⅛ car-miles per 10,000 run. In the surface-contact system as installed at Wolverhampton, any accident or breakdown can only affect one, or, in very rare cases two boxes, and the momentum of the car is sufficient to enable it to coast over the short length of track thus disabled. Further, any faulty box can be removed and replaced by a new one in an average time of 15 mins. without any interruption of service, while in an accident of any kind to the overhead equipment, it usually means the putting out of service temporarily from a quarter to half mile of route, and a total cessation of traffic along the section affected for a more or less lengthy period. *Cost of Operation and Maintenance*:—The expenditure on the maintenance of the contact system at Wolverhampton for the past 12 months, works out at £21 6*s.* per mile of single track or at 0·11*d.* per car-mile. In respect of car equipment, the cost per car per annum was £12 9*s.*, or per car-mile 0·144*d.* The latter item is in the author's opinion abnormal, and considerably in excess of what may be expected in future. It is impossible to obtain reliable figures as to the cost of inspection and maintenance of the trolley wheels, poles and standards in the case of the overhead system, as records are apparently not kept, but it is probable that the car equipment of the overhead system can be more cheaply maintained than that of a surface-contact system. One of the most serious disadvantages of the surface-contact system is the increased consumption of electrical energy involved, of which there are three causes:—(1) The energy required to operate the circuit-closing mechanism of the track equipment. (2) The additional energy necessary for the propulsion of the cars owing to the extra weight of the special apparatus carried on the cars. (3) The surface leakage from box to rail over the paving under each car. The average current consumption for the twelve months worked out at 1·49 units per car-mile. Of this the additional current consumption due to the weight of the Lorain equipment is approximately equal to 0·13 unit per car-mile, and the total additional current consumption to be debited against the surface-contact system is 0·24 unit per car-mile, or approximately 19 per cent. more than what would have been required by the overhead system. *Disfigurement of Streets and Obstruction to Traffic.*—This, in the case of the overhead system, is obvious; while it is claimed for the surface-contact system that it offers less impediment to the free use of the streets and side-walks than any other system, and on the score of appearance it may be said that it is the least conspicuous and objectionable of any other system. *Conclusion.*—The conclusions arrived at may be summed up as follows:—A well-designed and carefully installed surface-contact system is superior to the overhead trolley system in respect of the questions of safety, reliability, disfigurement of streets, and obstruction to traffic. The overhead system is considerably cheaper, both as regards the capital cost of installation and the annual cost of operation and maintenance. For tramway systems where low initial cost and low annual charges are the first consideration, and especially for light railways in thinly populated districts, the overhead system is to be preferred. In many of our larger towns, and especially at watering places and other pleasure resorts, the surface-contact system has many claims for serious consideration in preference to the overhead trolley system. *Cost of Installation.*—It may be taken that first-class overhead construction costs from £1,500 to £2,000 *per mile of route*, whether double or single, whereas the cost of the surface-contact system will be from £2,000 to £2,500 *per mile of single track.*—*Paper read before the Incorporated Municipal Electrical Association. Electrician, July 1st, 1894.*